IMPACT OF GREEN BUILDING IMPLEMENTATION TO PROJECT BUDGET

by

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ABSTRACT

IMPACT OF GREEN BUILDING IMPLEMENTATION TO PROJECT BUDGET

Global environmental problems such as climate change, resource and water depletion became more and more visible in the last decade and they deeply affect the future of the humankind. Buildings have a large impact in these problems because they consume a considerable part of produced energy and clean water in the world. Green building is the practice of creating structures and using processes that are environmentally responsible and resource-efficient. Green buildings offer a solution to the global problems and thus they became more popular in recent years via established green building certification systems. However, there are still questions in the construction sector about the effects of green buildings to project budget. This study is based on the investigation of the factors creating impact on the green building project budget in Turkey. Four LEED Gold and Platinum certified buildings are examined as case studies. Considering the findings of this study, it can be concluded that the impact of green building implementation on the project budget are affected by the level of desired green building certification, scope of construction work (whether it is core and shell or fully built building) and qualities of initial concept design before consideration of certification. Also, water and energy efficiency goals can be met with different strategies which can lead different green building cost impact. Concept design of a green building should consider green building strategies as early as possible to achieve a cost effective green building.

ÖZET

YEŞİL BİNA UYGULAMASININ PROJE BÜTÇESİNE OLAN ETKİSİ

İklim değişikliği, doğal kaynakların tükenmesi ve enerji üretim yetersizliği gibi küresel sorunlar her geçen gün daha çok açığa çıkmaktadır. Bu problemler insanlığın geleceğini derinden etkilemektedir. Binalar; dünyadaki enerji ve temiz suyun önemli bir bölümünü tükettikleri için bu problemlerin oluşmasında önemli bir rol oynamaktadır. Yeşil inşaat pratiği ise çevreye sorumlu ve kaynakları verimli kullanan yapılar yaratmaktadır. Yeşil binalar bu problemlere bir çözüm sunduğu için sertifikasyon sistemleri aracılığıyla daha popüler olmuştur. Fakat yeşil binaların proje maliyetine etkisi konusunda sektörde bir belirsizlik bulunmaktadır. Bu çalışma yeşil bina stratejilerinin proje bütçesine olan etkisini araştırmaktadır. Türkiye'de bulunan LEED Gold ve Platinum sertifikalı dört yeni bina çalışma kapsamında ele alınmıştır. Araştırma sonucunda yeşil bina maliyetini etkileyen en önemli maddelerin hedeflenen yeşil bina sertifika seviyesi, inşaat kapsamı (iç mekanların kapsamda olup olmaması) ve binanın sertifika kararından önceki konsept tasarımının nitelikleri olduğu belirlenmiştir. Binanın su ve enerji verimliliği hedeflerine farklı stratejiler izlenerek ulaşılabileceği ve farklı stratejilerin sabit maliyet üzerine farklı derece artışa sebep olduğu belirlenmiştir. Genellikle konsept tasarım aşaması ile ilgili olan maliyetleri düşürmek için yeşil bina kararının erken alınmasının ve yeşil bina stratejilerinin konsept tasarım esnasında bulunmasının etkili olduğu söylenebilir.

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LIST OF ACRONYMS/ABBREVIATIONS

AHU	Air Handling Unit
AP	Accredited Professional
ASHRAE	American Society of Heating, Refrigerating and Air-conditioning
BREEAM	Building Research Establishment (Environmental Assessment Method)
CE	European Conformity
CEDBIK	Turkish Green Building Association
CFC	Chlorofluorocarbon
CFD	Computational Fluid Dynamics
CO2	Carbon Dioxide
COP	Coefficient of Performance
DGNB	German Sustainable Building Council
DOE	United States Department of Energy Engineers
EPA	Environmental Protection Agency
ESC	Erosion and Sedimentation Control
FSC	Forest Stewardship Council
HVAC	Heating, Ventilation and Air-conditioning
ISO	International Organization for Standardization
LED	Light-emitting Diode
LEED	Leadership in Energy and Environmental Design
SCAQMD	South Coast Air Quality Management District
TCA	Turkish Contractors Association
USA	United States of America
USGBC	United States Green Building Council
VAV	Variable Air Volume
VOC	Volatile Organic Compound

1. INTRODUCTION

1.1. Background of the Research

Global environmental problems such as climate change, resource and water depletion became more and more visible in the last decade and they deeply affect the future of the humankind. Buildings have a large impact in these problems because they consume a considerable part of produced energy and clean water in the world. United Nations World Commission defines sustainability the as the concept of meeting the needs of the present generation without compromising the ability of future generations to meet their own needs. In recent years, sustainable buildings or green building practice became popular in the construction sector and academic fields with the increased global warming, resource depletion, building related health problems and, energy and water costs. The direct and indirect impacts of the building through its life-cycle rise their importance as a research area (UN, 2013).

In order to lead and accelerate the change towards to sustainability in construction sector, methods are developed including mandatory governmental regulations and optional green building certifications. In most countries, governmental sustainability regulations are criticized to be not sufficient where green building certifications are applicable in all countries and they are getting more popular in the construction sector without governmental obligation. Green building certifications evolve continuously to raise the level of standards higher than the industry and governmental regulations. They aim to reduce adverse impacts of buildings on environment, reduce the operational costs of buildings and increase the indoor air quality in the buildings. Recently, they also become a marketing tool which increased their popularity drastically (USGBC, 2009).

1.2. The Research Problem

Sustainability concept and green buildings offer a solution for the global environmental problems and thus they become more popular in recent years all over the world. There are more than 100,000 green buildings in the world and more than 200 buildings that obtained a green building certification in Turkey. However, there are still uncertainties in the construction sector about the impact of green buildings to project budget (Ozturk, 2015).

Review of literature shows that there are some studies about green building costs in developed countries however there is not many related studies in Turkey. This research is based on investigation of effects of green building to project budget and the ways in which such projects can be completed cost effectively in Turkey.

1.3. Purpose of the Study

The purpose of this research is to analyze the green building implementation and additional costs of green buildings. It is aimed to find out which strategies implemented in green building projects result in increased project budget. This research is expected to help professionals who intend to implement such projects in Turkey successfully.

In this respect, following are the objectives of this research:

- Examining sample green building projects in Turkey,
- Finding the cost drivers on different samples,
- Determination of additional costs which are present in these projects in Turkey,
- Recommendations on managing the budget of green building projects.

1.4. Related Studies

Research studies about green building implementation have been popular over the last few years in Turkey and the World. There are studies about green building energy performances (Diamond *et al.*, 2006; Fowler *et al.*, 2010; Sinou and Kyvelou, 2006; Bell, 2004), certification systems used in Turkey (Ozturk, 2015 and Yalcin, 2014), barriers for green building (Gundogan, 2012), green building certification systems, conversion of existing building to green buildings (Aktaş, 2013). However, there are few studies about green buildings impact on project budget and they are mostly applicable for U.S. or Europe.

Kats (2003) “Green Building Costs and Financial Benefits”, Capital E, pp. 2-8; contains statistical informational about 33 LEED certified buildings located in United States. The report concludes that financial benefits of green design are between 50$ and 70$ per square foot in a LEED building, which is over 10 times the additional cost associated with building green.

Nalewaik, and Venters (2008) “Costs and Benefits of Building Green”, 2008 AACE International Transactions; reviews different reports in the area to have a broader conclusion. The report claims that some industry data indicates that green construction is more expensive than traditional building, with other conflicting studies indicating that green construction is no more expensive - since the LEED certification concept is still young, comparative data and controlled studies are hard to obtain.

Mapp *et al.*, (2011); analyze the initial building costs for two Leadership in Energy and Environmental Design (LEED) banks and eight non-LEED banks with similar building types and sizes located in western Colorado. The study finds that the building costs of the LEED banks are similar to and within the same ranges as non-LEED banks. Additionally, costs associated with seeking LEED certification is estimated to be below 2% of the total project cost. However, the studied LEED Certified buildings level is LEED - Silver which is a low-level LEED certification (Mapp *et al.*, 2011).

A recent study, Luay and Kherun (2016), analyzed different empirical studies about green building costs and found out that green building costs can occur in a range from -0.4% to 21%. The study concluded that there is significant gap in the cost premium range.

1.5. Research Method

Case study methodology has been applied in this research to gain a better understanding of project based implementations. Case studies will be performed on different green building projects in Turkey. Face to face interviews will be made with professionals involved the project.

1.6. Scope and Limitations

Green building is a wide concept which is implemented in all types of buildings. Different types of buildings have different ways of receiving green building certifications and may have different budget effects. Thus, to have a solid base for cost calculations only newly built office buildings will be chosen in the research.

There are many green building certifications in the world but LEED is the most popular certification all over the world. When green buildings which are certified in Turkey are investigated, it can be seen that LEED is the most common certification. LEED has different certification levels and lower levels may not have significant impact on project budget. "Platinum" is the highest level of LEED certification. In order to have a solid baseline for the research, only LEED Platinum certified newly built office buildings will be evaluated.

1.7. Organization of Thesis

In the second chapter of this thesis, history of green buildings, worldwide known certification systems, green building trends both in the world and Turkey and general items which may cause budget increase are explained. In the third chapter, research methodology is presented and general information about case studies in this research is given. Case studies are described with all available information and green building implementation and project budget difference are explained in detail in the fourth chapter. Findings are presented and discussed in the fifth chapter. In the last chapter, conclusions are drawn.

2. GREEN BUILDINGS

2.1. Climate Change and Buildings

Scientists agree that natural balance on earth is disturbed and natural resources are over consumed by human activities. The results of the human impact are already seen today. Global and local climate change, depletion of natural resources, extinction of natural life, desertification of agricultural land, increasing of the ocean level and famines around the world are some of the results came to light. It is estimated that these results will get worse in the near future due to rapid population growth, uncontrolled consumption of natural resources, increase in energy and water consumption and higher carbon emissions. It is foreseen that failure to reduce the environmental impacts of human activities will have deeper and irreversible effects on nature and human development. As one example of these results, it is estimated that about 200 million people will have to migrate because of the climate change in 2050 (Brown, 2008).

There is strong evidence that climate change and related issues occurring can be attributed to human activities. They are caused both from the unconsidered consequences of economic growth of developed countries and lack of development and equity in poorer countries (UN, 2016).

Negative environmental impacts are mostly seen the result of the pollution generated by the rising living standards and growing demand on scarce resources. Economic growth increased the living standards in the world. However, it has been achieved without consideration of environmental effects and it globally damaged the environment. Mostly, economic improvement has been based on the free or cheap access to natural resources including raw materials, energy, chemicals etc. Environmental pollution and burden on the nature were not considered as costs during these processes. It was not foreseen that these trends will have deep, cumulative and global environmental effects (UN, 2016).

Undeveloped countries with lower living standards contributed to the environmental pollution in a different way. They destroyed the environment in order to survive and develop. In these countries; population grows uncontrolled, forests are cut down, fertile land is destroyed, unequal growth prevents people to care for nature (UN, 2016).

Researches show that CO2 emissions in developed countries grew more than 20% in 60 years and the global warming danger as well (Nelson et al, 2010). A 5° Celsius rise in global temperature, which has 50% possibility, causes a 10% loss in global economic output (UKGBC, 2012).

Study of McGraw-Hill (2008) shows that buildings in general are the largest consumers of natural resources in the world and thus the largest cause for climate change. Buildings are accounted for 40% of total global CO2 emissions, 30% of global raw materials consumption and 30% solid waste output. Research shows that the U.S., Russia and the European countries have also similar rates as shown in the Figure 2.1 (IEA, 2008). Construction and operation of buildings contribute almost half of the total energy consumption in industrialized countries. When the energy sector's impacts are considered, it can be seen that the energy sector emits almost 90% of CO2 and 70% of greenhouse gases according to the UN (Garg *et al.*, 2006).

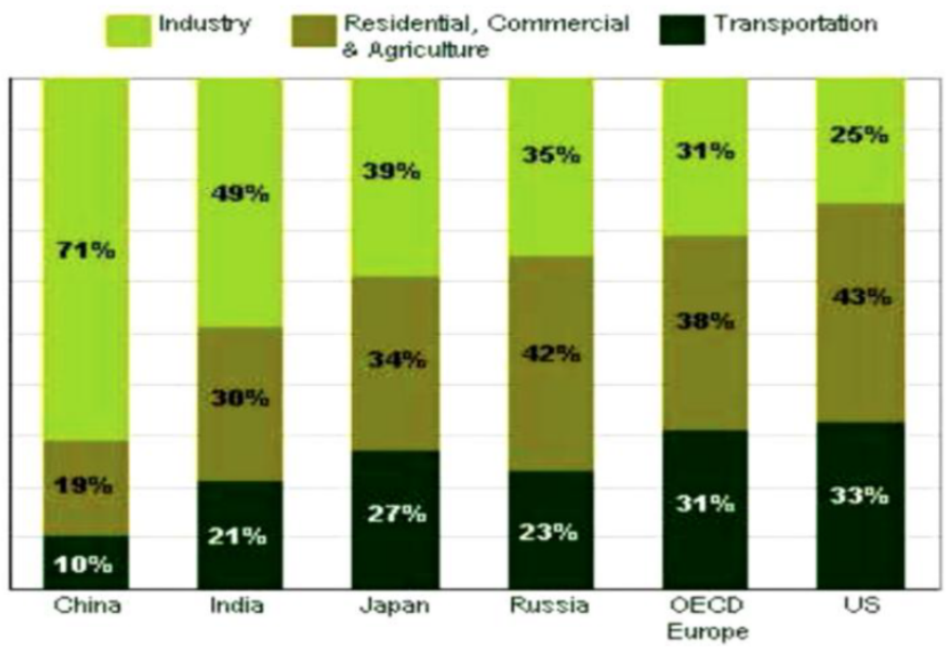

Figure 2.1. Global Energy Demand in 2005 (IEA, 2008).

2.2. Building Indoor Environment Quality

Humans spend most of their time indoors. Thus, building design and indoor air quality play a curial role in people's lives. Scientists agree that badly designed indoor spaces and poor indoor air quality decreases of human health and productivity in the long term. This affect is main named as sick building syndrome. In a US report (Kreiss, 1990), office workers are surveyed at random; 24% of them are reported to have air quality problems in their work place, and 20% claimed that this problem disturbed their ability to do their job effectively.

Kreiss (1990) listed the symptoms of sick building syndrome as headaches and dizziness, nausea (feeling sick), aches and pains, fatigue (extreme tiredness), poor concentration, shortness of breath or chest tightness, eye and throat irritation, irritated, blocked or runny nose, skin irritation (skin rashes, dry itchy skin). Some people may also suffer allergic reactions and asthma when exposed to poor indoor air quality.

Additional research shows that sick building syndrome is strongly related to personal factors such as reported hyperreactivity and sick leave due to airway diseases. Other results associated with the sick building syndrome are smoking, psychosocial factors, and experience of static electricity at work. As shown on the Figure 2.2; number of symptoms increases with the total indoor volatile hydrocarbon concentration which are mainly emitted by the materials used indoors (Norback *et al.*, 1990).

2.3. History of Green Building Concept

U.S. Environmental Protection Agency defines green building as the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle, including design, construction, operation, maintenance, renovation and deconstruction. Green building practice includes concerns of the economy, utility, durability and comfort in a way that it expands the conventional building goals. Generally, green building can also be called as sustainable building (EPA, 2017).

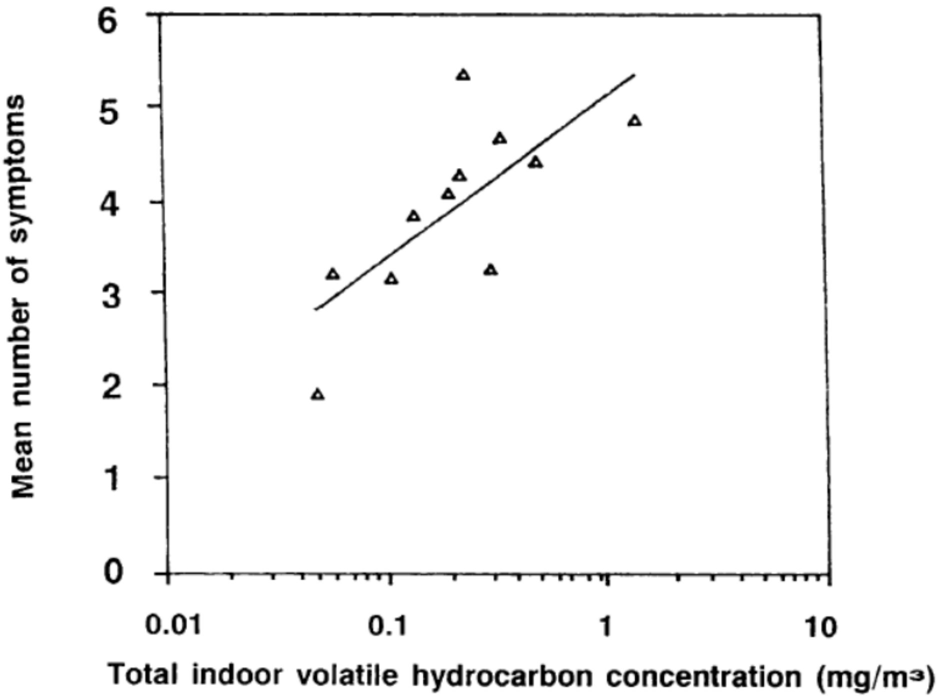

Figure 2.2. Linear regression values of the mean (arithmetic) number of symptoms (range 0-16) as a function of the total indoor concentration of volatile hydrocarbons (Norback *et al.*, 1990).

The green building concept became popular in 2000s but the beginning of the concept dates back to 1960s. The milestones of green building movement is shown on the Figure 2.3. In 1962, the book "Silent Spring" authored by Rachael Carson had started a nationwide debate on the unrestricted use of the Dichloro-Diphenyl-Trichloroethane (DDT) and other pesticides by the government. Environmentalist across the world are united around this debate to show the environmental effect of industrialization. (Potbhare, 2009).

It was the In 1970s, during the OPEC oil embargo oil crisis forced the architects and engineers to design more efficient buildings. ASHRAE (American Society of Heating and Air-Conditioning Engineers) published the first widely used energy efficient design standard in 1975 which becomes a widely used code for energy efficiency in the future. ASHRAE defined all building properties including building envelope, lighting, heating, cooling and ventilation according to different climate zones (Potbhare, 2009).

In 1980s the Passivhaus concept is established in Europe which sets the bar higher than ASHRAE and requires buildings that require very low energy by using passive design strategies. Passivhaus standard was a milestone for European energy codes and building design practice. It has been used very widely and most of the energy codes are influenced from this standard. (Eric Fischer, 2010). In 1983, U.N. General Assembly had created the World Commission on Environment and Development which is famously known as the “Brundtland Commission”. The commission prepared “Our Common Future” report in 1987 about the sustainable development.

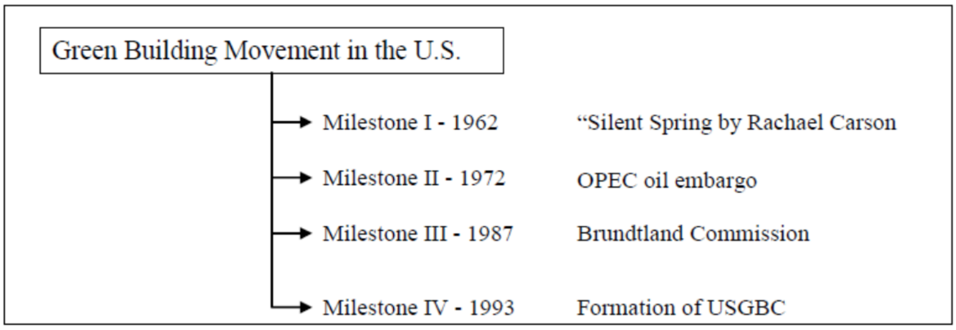

Figure 2.3. Milestones that triggered green building movement in the U.S. (Potbhare, 2009).

In 1990, BRE (Building Research Establishment) in United Kingdom published BREEAM (Building Research Establishment Environmental Assessment Method) the first widely used green building certification system. Unlike ASHRAE and Passivhaus standards, BREEAM included more than energy efficiency; it also included other aspects of a green building: Land use and ecology, management, health & wellbeing, transport, water, materials, waste and pollution. In 1992, Energy Star program has established by US Environmental Protection Agency which is a certification tool for electronics products used in building in order to promote energy efficient appliances. US Green Building Council (USGBC) was launched in 1993 as a private non-profit organization and established LEED (Leadership in Energy and Environmental Design) green building certification system in 1998 which later became the most widely used certification system in the world. LEED was based on the BREEAM certification and included similar categories.

Many green building certification systems are launched around the world in order to fit the local conditions of the country. There are some new generation green building certification systems which evaluate the green building from a wider aspect including social and economical aspects. One the most popular new generation certification system is launched in Germany named DGNB (Deutsche Gesellschaft für Nachhantiges Bauen). Libing Building Challenge is another certification which is launched in the U.S.. The certification focuses on the measured performance of the building during its life where other certifications focus on the design and expected performance (Potbhare, 2009).

In the meanwhile, building energy codes are developed according to international agreements and protocols. European Union launched 2010 Energy Performance of Buildings Directive and the 2012 Energy Efficiency Directive as the main legislation for building energy efficiency (Ozturk, 2015).

In Turkey, first modern green building was constructed in Middle East Technical University, The Solar House, in Ankara, in 1976. Several solar houses followed as exemplary buildings but there weren't any commercial green buildings built until 2000s. In 2007, Turkish Green Building Council is founded as a non-profit non-governmental organization to increase the awareness and to spread the green buildings in the construction sector. In 2012, the council began to work for a local green building certification system for residential buildings with the help of universities, governmental and sector representatives (Ozturk, 2015).

The popularity of green buildings resulted a shift in the real estate sector both in Turkey and in the World. According to a survey which is made by more than 1000 companies in construction sector showed that 24% of companies have already participated in a green building project and 60% of the companies expect to participate in a green building project by 2018 (Dodge, 2015). Market report presented by U.S. Green Building Council shows that there are more than 75,000 buildings which are certified by a green building certification. Construction projects which are registered to achieve LEED is 1.2 billion sqm. and the value of green market share is estimated as

260 billion USD. In Turkey, the total floor area of LEED certified buildings is 3 million sqm. and LEED registered projects that are under construction include 24 million sqm (USGBC, 2015).

2.4. Benefits of Green Buildings

The main idea to construct a green building is to reduce the environmental impact of buildings in many aspects. Sustainable building practice decreases the impact on environment by enhancing and protecting biodiversity and ecosystems, by improving air and water quality, by reducing waste streams and by conserving and restoring natural resources. Since the impacts of global climate change and scarce natural resources are getting more visible every day, it is clear that the most important benefit of a green building is its environmental benefits. Additionally, concerns for energy security and countries energy dependence are increasing with the increasing demand on the fossil fuel resources (EPA, 2017).

The main feature of the green building is to be energy efficient to solve the global energy problem. Reduction of energy consumption and CO2 emissions are one of the most important advantages of green buildings. Green buildings can be 30-50% energy efficient and make 35-40% less CO2 emissions (UNEP, 2012). 121 LEED certified buildings are examined by a study of Turner & Frankel (2008). The study took place in a one-year period and energy usage of the buildings are measured. The results showed that the median energy consumption per unit area of LEED certified buildings are 32% lower than the mean provided by Commercial Building Energy Consumption Survey (CBECS) 2003 database. The study also points the large variability of the performance data.

Fresh water is also becoming a scarce resource in many regions around the world. Green buildings are essential for the efficient usage of water, which gains more importance considering depletion of water resources. Additionally, the process to transport potable water to buildings consumes enormous energy in pumping, transport, and treatment. A green building uses water efficiently and reuse whenever possible. Water consumption may be reduced with water efficient appliances and fixtures, consciously usage behaviors, responsible irrigation and water-reuse methods. Green building can achieve 30-50% savings in water usage (UNEP, 2012).

Green building practices about waste management is another significant aspect. Encoring recycled and recyclable material usage, reusing existing buildings and choosing responsible materials provide remarkable resource efficiency. In green buildings, there may be 50-90% less waste production (UNEP, 2012). It is also crucial to optimize the use of materials and waste in order to protect natural resources and prevent pollution. Green building practice aims to use environmentally responsible raw materials whenever possible during the entire life of the building (Demir, 2013).

There are also other important benefits affecting people's choice to construct green. High performance construction contributes to reduce operating costs, to create, expand and shape markets for green products and services and to optimize life cycle economic performance. Research shows that there are significant economic motivators associated with green buildings in terms of life cycle costing, employee productivity gain and property values to building participants. The first comprehensive study about green building impact on project budget showed that an extra capital investment about two percent of total construction cost can provide up to ten times life cycle savings (Kats *et al.*, 2003). Financial benefits are derived by lower energy, water and waste costs during building life and better indoor air quality and increased occupant productivity. Another study commissioned by The General Services Administration (2004) examined 12 LEED certificated buildings in U.S. The results show that that green buildings have less operation costs and better energy performance.

The green building approach supports to enhance occupant comfort and health, to minimize strains on local infrastructures and to improve overall quality of life. All green building certification system includes criteria about daylighting, natural ventilation and improved air quality benefits. These benefits provide enhanced occupant productivity and health, as well as reduced absenteeism and illness. A wide survey has been conducted about occupant satisfaction in green and non-green office buildings.

The results revealed that green building occupants were more satisfied with thermal comfort and air quality in their workplace on average. (Abbaszadeh *et al.*, 2005). Another research made by Victoria and Kador Group (2008) showed that green offices have significant positive impact on employee productivity and satisfaction.

2.5. Common Green Building Practices

Research shows that there are different strategies and measures to create a green building which reduces the environmental impact and increases the indoor air quality. These strategies adopt the local conditions and climate. The importance and impact of these strategies may change according to regional priorities. Also designers find different ways to solve the same problem. All in all, green building design is a way of thinking for the building design (USGBC, 2009). Passive design strategies incorporated with the building design is one of the properties of a green building. These strategies are most efficiently implemented by an integrative project management. Some of these strategies are shown on the Figure 2.4 on a sample project, namely, Barclaycard Building). These strategies include natural ventilation through air stack effect, building layout and shading devices according to sun path, light shelves to provide indirect daylighting, landscaping and lakes to modify the air temperature. Although there is not a fixed receipt for green building design, there are main categories which all green buildings must consider (Brian, 2006).

Optimize site potential: Creating a green building starts with proper site selection, including consideration of the reuse or rehabilitation of existing buildings in order to reduce raw material usage. The location, orientation, and landscaping of a building affects local ecosystems and energy consumption. For example, it is wiser to select a site oriented to sun in colder climate. Transportation methods available in the close region impacts the carbon emissions of occupant's transportation. Smart growth principles are incorporated into the project development process to ensure that the building connects the surroundings in a meaningful way. Occupants should not travel far to reach basic services. Locations of bicycle and pedestrian roads, vehicle barriers, and perimeter lighting are crucial in green building design. Landscape design must be integrated with the green building principles. Plants used in the site should be native or adapted so that local fauna is not disturbed. The site of a green building is designed to control and treat storm water runoff to prevent sedimentation in underground water (USGBC, 2009).

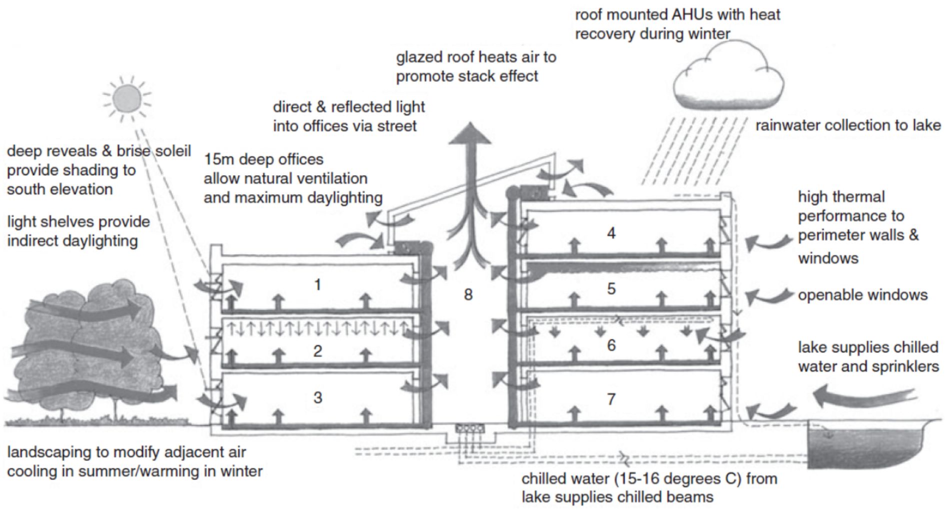

Figure 2.4. Cross section through Barclaycard Building, Northampton, designed in 1996 by Fitzroy Robinson and Partners showing the various environmental measures adopted (Brian, 2006).

Optimize energy use: The most important aspect of green building is to increase energy efficiency and maximize the use of renewable energy resources. Governmental energy efficiency regulations and private sector are shifting towards net zero energy building design in order to deal with the global energy problem. A green building considers natural ventilation strategies and passive heating cooling strategies in order to minimize the load on mechanical systems. Sun shading devices are designed according to sites sun orientation. Building envelope insulation values shall be suitable for the local climate. Highly efficient and local climate adapted heating & cooling systems are designed. Lighting in the building is controlled by daylight or occupant sensors and use efficient luminaire. Renewable energy systems such as solar panels should be implemented. Energy systems of the building are monitored throughout the building life in order the find deficiencies and optimize according to building occupancy (USGBC, 2009).

Protect water: A green building should use water efficiently and reuse whenever possible. Low consuming water fixtures such as sensor based lavatory faucets, waterless urinals, dual flush toilets are common green building practices. Waste water collected from showers and faucets can be treated and used in water closets and irrigation. Rain water in suitable climates can be re-used for various purposes. Also monitoring the water consumption is an important aspect, metering of water and informing building occupants helps to reduce water consumption (USGBC, 2009).

Optimize material use: Green building aims to minimize the life-cycle impacts of materials which has causes such as resource depletion and human toxicity. Selection of local materials to prevent carbon emission of transportation, renewable materials to reduce the future waste, green certified materials which prove that environmental is less harmed during harvest and production are some of the strategies (USGBC, 2009).

Enhance indoor environmental quality: Utilization of day light, increased ventilation, moisture control, enhanced acoustic performance and reduced indoor air pollutants are properties of a green building. Green building practice also emphasizes occupant control over lighting and temperature to improve comfort and productivity (USGBC, 2009).

Optimize operational practices: Green building strategies should continue through the buildings life to operate the building as it is designed. Management of energy and water consumption, purchase of preferred materials, regular maintenance works, management and recycle of waste, occupant education are some of the items that can be implemented during buildings life (Yates, 2014).

2.6. Common Green Building Capital Cost Items

The costs of green building are perceived as the biggest obstacle towards green movement in the construction sector. A survey conducted by McGraw-Hill with 700 construction professionals showed that 80% of professional considers "higher first costs" as an obstacle to green building (McGraw-Hill, 2008). Another survey made by the

World Business Council for Sustainable Development found that business leaders believe that green building is, on average, 17% more expensive than conventional design where the average reported cost increase is 1.5% as shown on the Figure 2.5 (WBCSD, 2007).

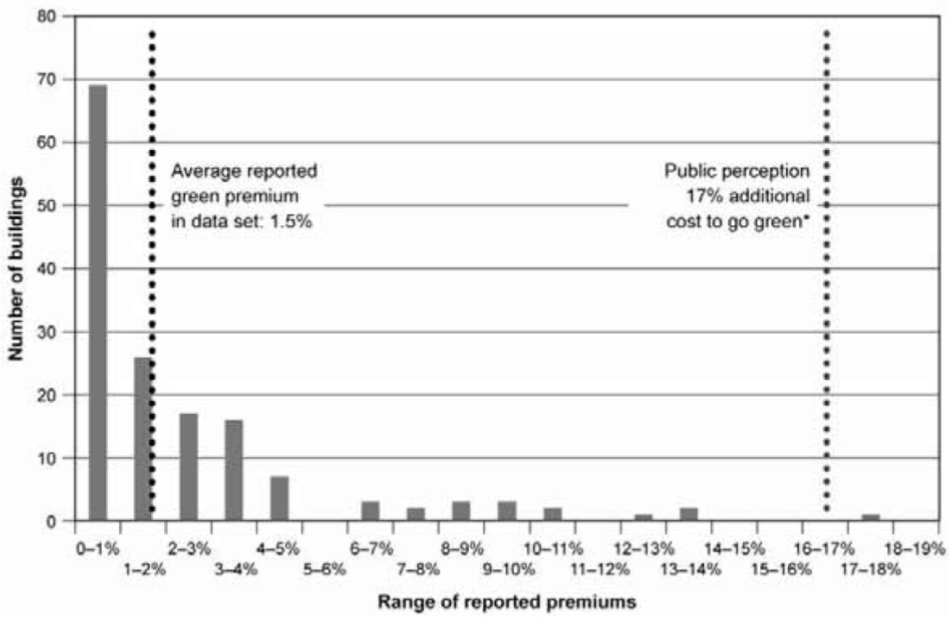

Figure 2.5. Reported and Perceived Green Premium for Buildings (WBCSD, 2007).

Green building is a comprehensive approach to building design and construction as explained in this chapter. Green building practices require changes or additional implementation which may result in an increase of project budget. The research about first cost increase is done mainly according to LEED certification since LEED is accepted as an international green buildings certification system. In the U.S., There are academic and sectoral research done about the green building costs. In Turkey, there aren't any comprehensive studies conducted regarding green building cost increase.

The book "Green Building Costs and Financial Benefits" by the author Gregory H. Kats includes the first comprehensive studies about green building costs. It is explained that green building concept is the sum of many strategies. In order to evaluate the green building costs, it is needed to analyze these strategies separately. The building orientation and sustainable landscaping do not create significant costs if they are well designed. Site proximity to public transportation may have significant costs since sites with public transportation tend to be more expensive. Sustainable landscaping mostly does not have a cost (Kats, 2003).

Building design that considers natural ventilation, daylighting and passive heating cooling strategies in order to minimize the load on mechanical systems does not have significant costs but designers may need to put more time on the design. However, efficient mechanical systems, better insulation materials, efficient lighting, solar panels for renewable energy result in high capital costs. Waste water treatment and re-use also has a high impact on capital costs. Building materials with better sustainable properties are generally more expensive than traditional building materials (Kats, 2003).

Another aspect mentioned in the book is that it is important to understand that some green buildings may be greener than others and some buildings may be considered green even by itself without any improvements. Also, the decision phase for a green building has an effect to the costs. Projects that decide to be green in later phases face with higher costs (Kats, 2003).

Kats, emphasizes the difficulties to achieve the cost data of green buildings since no data has been collected how much the building would cost as a conventional building rather green building. In order to do a useful analysis, cost data should include both green and conventional design and construction scenarios of the same buildings (Kats, 2003). Kats (2003) surveyed 30 green school projects that were built in U.S. and it is estimated that green design caused 1-2% additional costs.

Similarly, another research showed that the cost to achieve LEED certification can depend upon a variety of factors and assumptions, including:

- Type and size of project;
- Timing of introduction of LEED as a design goal or requirement;
- Level of LEED certification desired;
- Composition and structure of the design and construction teams;

- Experience and knowledge of designers and contractors or willingness to learn;
- Process used to select LEED credits;
- Clarity of the project implementation documents;
- Base Case budgeting assumptions (Syphers, 2003).

A study done by Northbridge Environmental Management Consultants (NEMC) for the American Chemistry Council examined the cost categories of LEED certification. In the study costs are divided into three categories: i) Soft costs including documentation, commissioning, consultancy fees; ii) Improving system efficiency including investments justified with payback time and worker productivity; iii) Reducing environmental impacts including implementation with no market value (NEMC, 2003).

U.S. General Services Administration (GSA) prepared a LEED cost study in 2004. Two mid-rise office buildings built by GSA are examined in order to determine costs for different certification levels. The green building costs are divided as construction and soft costs. Construction costs are evaluated for each credit as no cost, low cost, moderate cost and high cost. Each credit and prerequisite is assigned one these cost types. Soft costs are divided as LEED design costs and LEED documentation costs. Design costs include tasks that increase the design team's scope of work. Documentation costs include LEED related reports and certification fees. Results show that impacts for the Certified and Silver rated scenarios fall below the 5% and below 10% for Gold level (GSA, 2004).

Another study examined additional costs of a dormitory buildings LEED Silver certification. The study evaluated costs of each credit achieved. Highest costs are related to energy performance credit, LEED consultancy fees and commissioning costs. Total cost premium of the building is estimated between 1% - 2.8% (Stegall, 2004).

Davis Longdon's study (2007) concluded that a 5-star green building according to GREEN STAR certification system had a 3-5% premium with respect to a non-green counterpart. Fowler and Rauch (2008) reported that the capital cost increase of LEED certified buildings range from 1% to 8% according the level of LEED certification.

Another research done in 2008, claims that it is not possible to conclude a rule for green building costs since there is high variety in different projects. Nalewaik, A. and V. Venters report (2008) claims some industry data indicates that green construction is more expensive than traditional building, with other conflicting studies indicating that green construction is no more expensive.

Deloitte & Touche LLP (Deloitte) was engaged by Alberta Infrastructure to undertake a LEED Gold Certification Cost Analysis. Three building projects are examined in detail to find out the cost increase in Case of a LEED Gold certification. The costs are divided as hard and soft costs and evaluated credit by credit. Highest costs were related to energy performance credit and LEED consultancy and certification fees. The project budget increase for LEED Gold certification is found out as 4 - 7% for these projects (Deloitte, 2008).

Another study which examined 13 LEED Certified Hospital projects in terms of cost increase found out that the green building cost premium is between 0-5%. However, there is no single industry standard or baseline definition to identify first-costs of green buildings, yet there is widespread presumption that a consistent definition exists (Houghton 2009).

Mapp *et al.*, (2011); analyses the initial building costs for two Leadership in Energy and Environmental Design (LEED) banks and eight non-LEED banks with similar building types and sizes located in western Colorado. The study classified the LEED associated costs as i) total building cost and cost/sf, ii) soft costs and iii) direct costs. Total buildings cost and cost/sf included the hard costs of construction and site work. Soft costs included any costs related to project management, project schedule and additional design time. According to study, there is no additional soft costs included. Direct costs are directly related to LEED certification such as LEED consultancy fees, LEED certification fees, energy modeling fees and commissioning fees. The study finds that the building costs of the LEED banks are similar to and within the same ranges as non-LEED banks. Additionally, costs associated with seeking LEED certification is estimated to be below 2% of the total project cost. However, the studied

LEED Certified buildings level is LEED - Silver which is a low-level LEED certification (C.Mapp *et al.*, 2011).

Nyikos *et al.*, (2012) collected construction, cost, and utility data of 160 LEED certified buildings and analyzed them using simple correlation and descriptive statistics. It is found that cost premium is ranged from 2.5 to 9.4% with a mean of 4.1%.

Another study conducted cost analysis of theoretical models of green office buildings with different sizes. The findings of this study estimates the excess cost of green building between 0-10% (Gabay, 2014).

A recent study; Luay N., D. and Kherun N., A. (2016), analyzed different empirical studies about green building costs and found out that green building costs can occur in a range from -0.4% to 21%. The study concluded that there is significant gap in the cost premium range.

2.7. Common Green Building Operational Cost Differences

There is not much research done about the operational costs and benefits of a green building. Kats (2003) states that generally, it is accepted that green buildings consume less energy and water which results in lower operational costs. However, some strategies used in green buildings may have higher maintenance costs than traditional buildings such as water treatment. Thus, it is important to evaluate operational costs separately for each green building (Kats, 2003).

A research conducted by Nyikos et al. (2012) claims that operating costs in LEED certified buildings were $0.70 per square foot less than non-LEED buildings. The research of GSA Public Building Service (2011) shows that GSA's green buildings have 28% less energy cost, 12% less maintenance cost and 19% less operational costs.

2.8. Government Regulations in Turkey and the World

Green building movement has become popular in the sector all around world both voluntary and mandatory ways. Almost all developed and developing countries are published their own regulations in order to increase efficiency in building design in different levels.

In U.S., ASHRAE 90.1 standard is the mandatory energy efficiency regulation for all new buildings which is updated continuously and sets the bar higher for the building sector. ASHRAE is updated regularly to lead the building sector. ASHRAE 90.1-2016 is approved this year and in use at the moment. Additionally, some states use tax reduction incentives for green building certification systems such as LEED and Energy Star (Aksakal, 2015).

European Union launched 2010 Energy Performance of Buildings Directive and the 2012 Energy Efficiency Directive as the main legislation for building energy efficiency. The directives include obligation regarding energy performance certifications and building design efficiency standards for new and existing buildings. The European Portal For Energy Efficiency In Buildings (BUILD-UP) is also launched in order to coordinate European experts on energy reduction in buildings. The aim is to share information and best practices (European Commission, 2017).

In Turkey, Turkish Green Building Council established in 2007, was the leading organization for green building. In 2012, Turkish green building certification system preparation is begun and published in 2015. However, it is still in approval phase together with governmental institution, universities and public sector organizations (Aksakal, 2015).

Energy performance in buildings legislation is published in 2011 which is prepared according to European directives. This legislation mandates that from 2011 all buildings with an area larger than 50 m^2 to obtain an energy efficiency identity card and in 2020 all building including existing buildings must have an energy efficiency identity card (Aksakal, 2015).

2.9. Green Building Certification Systems

International certification systems which aim to serve world-wide become much more popular because of the wide recognition in the sector. There are more than 30 green building certification systems all over the world. Many countries have developed their own certification system to adopt local differences. BREEAM, LEED, Green Star, CASBEE, Living Building Challange, DGNB, Estidama Pearl and EDGE are the most popular and innovative green building certification systems used in the world. Information about these certification systems are given in the Table 2.1.

2.9.1. BREEAM (Building Research Establishment Environmental Assessment Method)

BREEAM is a voluntary measurement rating system for green buildings that was established in the UK by the Building Research Establishment (BRE) in 1990 in order to evaluate the environmental impacts of buildings economically and basically. There are 714000 BREEAM Certification application and 11600 certified buildings in the world (Gazioglu, 2012).

Ten categories of BREEAM rating system constitutes of Building Management, Health and Wellbeing, Energy, Transport, Water, Materials, Waste, Land use and ecology, Pollution and Innovation. These main topics differ country to country according to geographical conditions (BREEAM, 2013).

BREEAM certification levels are Pass, Good, Very Good, Excellent, and Outstanding. The research about BREEAM certified buildings showed that 4,5 million Co2 emission was decreased until now (BREEAM, 2013). Table 2.1 shows detailed information about the certification system.

Table 2.1 shows detailed information about the certification system.

Table 2.1. Green Building Certification Systems.

		BREEAM	**LEED**	**GREEN STAR**	**CASBEE**	**LIVING BUILDING CHALLANGE**	**DGNB**	**ESTIDAMA - PEARL**	**EDGE**
LAUNCH DATE COUNTRY		1990 U.K.	1998 U.S.	2003 Australia	2004 Japan	2006 U.S.	2008 Germany	2008 United Arab Emirates	2013 U.S.
INSTITUTION		BRE	USGBC	GBCA	JSBC	ILBI	DGNB	UPC	IFC
ASSESSMENT CATEGORIES		- Management - Health - Energy - Transportation - Water - Materials - Waste - Site and Ecology - Pollution - Innovation	- Sustainable Sites- Water Efficiency - Energy and Atmosphere - Materials and Resources - Indoor Environmental Quality - Innovation	- Management - Indoor Air Quality - Energy - Transportation - Su- Site and Ecology - Materials - Emissions - Innovation	- Energy - Resources - Local Environment - Building Environment	- Site and Location - Water - Energy - Health - Materials - Equity - Esthetics	- Environment - Economy - Culture - Technic - Management - Site	- Water - Energy - Materials - Livable Environment - Natural Systems - Integrated Development - Innovation	- Energy - Water - Materials
CERTIFICATION TYPES		- New Buildings - Existing Buildings - Interiors - Residential - Neighborhood	- New Buildings - Existing Buildings - Commercial Interiors - Residential - Neighborhood	- New Buildings - Existing Buildings - Commercial Interiors - Neighborhood	- New Buildings -Existing Buildings - Residential - Neighborhood	- New Buildings - Renovations - Neighborhood - Infrastructure	- New Buildings - Existing Buildings - Residential - Neighborhood	-New Buildings - Existing Buildings - Residential - Neighborhood	- New Buildings
CERTIFICATION LEVELS		- Pass - Good - Very good - Excellent - Outstanding	- Certified - Silver - Gold - Platinum	- 4 star - 5 star - 6 star	- C - B- - B+ - A - S	- Petal Certification - Living Certification - Net Zero Energy Certification	- Bronze - Silver - Gold - Platinum	- 1 pearl - 2 pearl - 3 pearl - 4 pearl - 5 pearl	One level
NUMBER OF PROJECTS	World	13000	30000	1440	450	250	1280	11300	32
	Turkey	49	171	0	0	0	1	0	0

2.9.2. LEED (Leadership in Energy and Environmental Design)

LEED is the most popular certification system all around the world. It became a well-known brand for green building practice. It is a voluntary, consensus-based, market-driven program that provides third-party verification of green buildings. It was launched by USGBC (U.S. Green Building Council) in 1998 in US and it has been evolving since. Every new version of LEED sets the bar higher. The new version of LEED (Version 4) has become mandatory for new projects in December 2016. Figure 1 shows the level and shift of LEED certification compared to versions and traditional building codes. As it can be seen on the figure energy codes are increasing with the LEED certification standard towards to zero and positive impact buildings (USGBC, 2017).

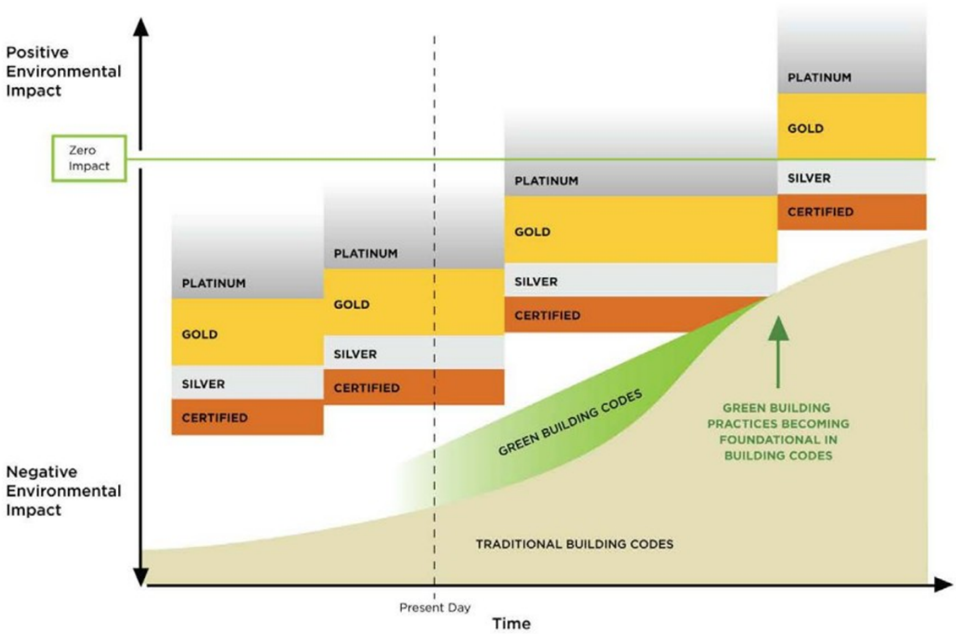

Figure 2.6. LEED Certification shift (Image captured from the USGBC Central Texas - Balcones Chapter "Austin Exclusive Sneak Peek: LEED v4 Presented By USGBC National" presentation).

As shown on the Figure 2.2, number of LEED certified projects is increasing every year in the world. Most projects are certified as Gold and Silver. In total, there are more than 30,000 certified projects. Figure 2.3, shows the number LEED certifications and their levels in Turkey. The number of certified projects are increasing except 2016. Platinum certified projects are also spreading (USGBC, 2017).

LEED claims to be a flexible certification system to be applied to all project types. Each rating system groups requirements that address the unique needs of building and project types on their path towards LEED certification. Once a project team chooses a rating system, they'll use the appropriate credits to guide design and operational decisions.

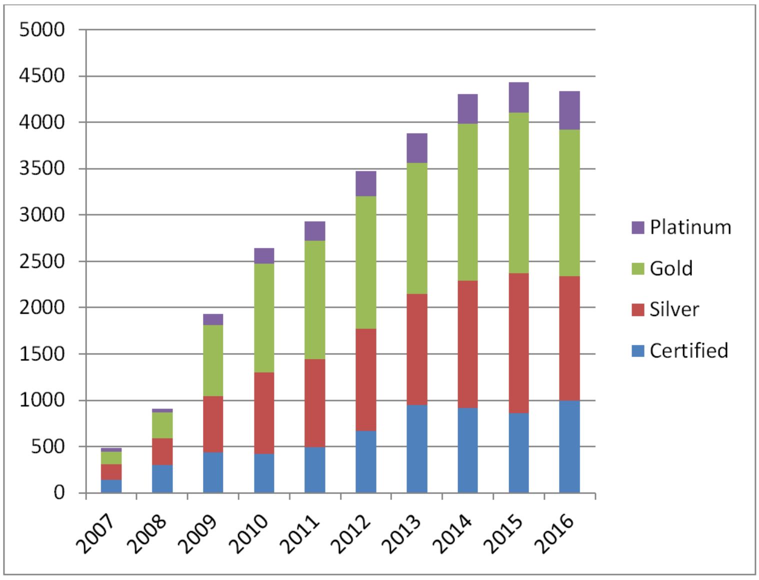

Figure 2.7. Number of LEED Certification each year in the World (USGBC, 2017).

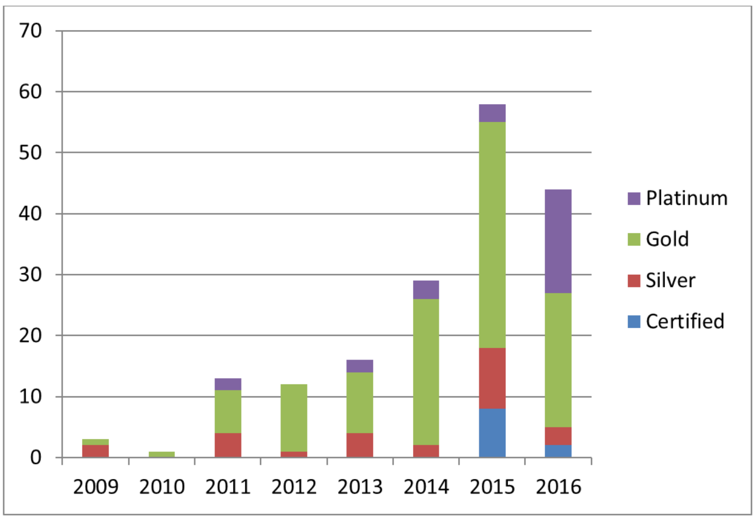

Figure 2.8. Number of LEED Certification each year in Turkey (USGBC, 2017).

There are five LEED rating systems that address multiple project types (USGBC, 2009):

- New Construction and Major Renovations: It is the appropriate rating system including all interiors, for new constructions and renovations of commercial buildings and / or high-rise (higher than 4-6 stories) residential buildings.
- Existing Buildings: All types of existing buildings with completed construction process (excluding homes) can be considered under this category. Existing Building criteria emphasize more on operation and maintenance issues of the buildings. Therefore, often without or with minor need for additional investment costs, the certificate can be obtained with the help of environmentally friendly procedures which are applied to the operational issues.
- Commercial Interiors: All the interior projects are certified under this type. It is an ideal system especially for interior projects in the core and shell buildings.
- Neighborhood Development: Large-scale land development projects or redevelopment projects conducted by government and private sector are eligible for this type of certification.
- Homes: All residential buildings up to 6 floors can be evaluated under this category.

Each rating system is made up of a combination of credit categories. Within each of the credit categories, there are specific prerequisites projects must satisfy and a variety of credits projects can pursue to earn points. The number of points the project earns determines its level of LEED certification. There are six credit categories as summarized below (USGBC, 2009):

- The Sustainable Sites category includes criteria about the surroundings of the building. The location and relationship with the environment of the building is the main concern of this category. The category rewards smart site selection with available public transportation services, bicycle roads, available public services and existing infrastructure. It also focuses on restoring natural habitat of the site and protecting local and regional ecosystems.

- The Water Efficiency category mainly focuses on the water efficiency including indoor water use, landscape irrigation, process water consumption and metering of water uses. In order to comply with the category low water consuming equipment and plants must be selected or alternative water sources such as grey water or rainwater should be utilized.
- The Energy and Atmosphere category includes criteria about energy efficiency of the whole building during the entire life. The criteria focuses on energy efficient design including architectural and electromechanical criteria. Also energy consumption monitoring and green energy production are considered in this category.
- The Materials and Resources category aims is to minimize the impacts of extraction, processing, transport, maintenance and disposal of building materials. It has criteria regarding raw material utilization, resource efficiency, enhanced waste management.
- The Indoor Environmental Quality category focuses to improve the building occupant health and productivity. It includes criteria regarding the air contaminants, ventilation rates, thermal, visual and acoustic comfort.
- Innovation category includes strategies that are constantly evolving and improving. This category aims to reward projects for innovative building features and green building strategies (USGBC, 2009).

The number of points a project earns determines the level of LEED certification from a total of 110 points. Buildings can qualify for four levels of certification (USGBC, 2009), Table 2.1 shows detailed information about the certification system. LEED Certified: 40-49 points, LEED Silver: 50-59 points, LEED Gold: 60-79 points, LEED Platinum: 80 points and above.

2.9.3. Green Star

Green Star is established by Australian Green Building Council in 2003. It is widely used in Australia, New Zealand and South Africa. There are 1440 Green Star buildings in the world. The certification is based on the BREEAM system and contains similar criteria. The buildings are assessed under nine different categories: management, indoor environmental quality, energy,transportation, water, site and ecology, materials, emissions and innovation.

Green star is first developed for new construction and then other types such as existing buildings, commercial interiors and neighborhood is developed. The projects are rated from 100 point scale and there are certification levels of 4-star, 5-star and 6-star (Gazioglu, 2012).

Table 2.1 shows detailed information about the certification system.

2.9.4. CASBEE (Comprehensive Assessment System for Built Environment Efficiency)

CASBEE is developed by Japanese Green Building Council in 2004 and it is a system based on life-cycle assessment which is accepted as a comprehensive way to assess buildings. There are 450 CASBEE certified project in Japan (CASBEE, 2017). CASBEE assessment categories are energy efficiency, resource efficiency, local environment and building environment. The scoring system is different than other certification systems. The ratio between life quality in the building and environmental impact is scored so that a building which provides higher life quality can have more environmental impact.

2.9.5. Living Building Challenge

Living Building Challenge is a relatively new certification system launched in the U.S. by Living Building Institute. There are 250 certified projects at the moment main located in the U.S. and Canada. The main difference of this system is that it is based on the actual performance rather than estimated performance during design. Thus, the buildings have to be completed and the performance should be measurable in order to apply for this certification. The assessment categories include site and location, water, energy, health, materials, equity and esthetics. The certification has three levels: Petal, Living and Zero Energy. In order to achieve Zero Energy certification the new energy consumption of the building must be zero for the measured year (Living Building Institute, 2017).

Table 2.1 shows detailed information about the certification system.

2.9.6. DGNB (Deutsche Gesellschaft für Nachhaltiges Bauen)

DGNB is a Germany based certification which has a more comprehensive and life-cycle approach including the buildings social and economic properties. DGNB's primary motivation is the pressing need for an internationally harmonized certification system with which to support and encourage the planning and evaluation of sustainable buildings around the world (Gazioglu, 2012).

Six categories which affect evaluation of buildings are ecology, economy, socioculture and operation, technique, and land use and time. This rating system based on the application of integrated sustainable design criteria which are defined at the beginning of the project (Gazioglu, 2012).

Benefits of the certification system are improvement in sustainability, certainty in cost and planning, decrease in risks, being a marketing tool of buildings, enhancing life cycle of buildings. Certification is able to be adapted to different countries according to traditional techniques and social conditions of countries (Gazioglu, 2012).

Table 2.1 shows detailed information about the certification system.

2.9.7. Estidama - Pearl

Estidama means sustainability in Arabic and it is a sustainability program which is developed by Urban Planning Council of Abu Dabi. Estidama - Pearl is the certification system developed as part of the sustainability program in 2008. It is most widely used certification system in the Middle East. In 2010, United Arab Emirates launched a law that requires all new buildings to achieve Estidama Pearl certification at minimum level. The system includes criteria about water, energy, materials, livable environment, natural systems, integrated development and innovation.

Table 2.1 shows detailed information about the certification system.

2.9.8. EDGE (Excellence in Design for Greater Efficiencies)

EDGE is developed by International Finance Corporation in 2013 aiming to provide an easier, faster and cheaper green building certification for the developing countries where there are vast amount of construction and having a larger impact than other certification system with its wide usage. Thus, the method of EDGE is simpler than other systems. It focuses on energy, water and material consumption and the assessment is quickly conducted by a free web-based software. After assessment a certified professional visits the building to control the implementation claimed in the software where other systems depend on provided documents and do not have site visits to control implementation. The certification has only one level and there are certified project in developing countries around the world (EDGE, 2017).

Table 2.1 shows detailed information about the certification system.

3. RESEARCH METHODOLGY

Case study is the main research method in this thesis. A detailed description of each phase of the research is provided:

First, the problem of the research was identified. After the identification of the problem was completed, a comprehensive literature review was conducted about green building, green building certifications and common practices. In particular, green building related costs were researched in order to obtain in depth knowledge about subject. Pre-interviews were conducted with green building consultancy companies to determine the first step in advancing in this topic. Based on literature reviews and pre-interviews, it was decided to conducted Case studies for a detailed examination of costs.

After literature review was done, the list of projects for Case study was prepared and suitable projects were selected. The questionnaire for the interviews was prepared according to LEED credits each project achieved in order to determine green building costs. After preparation of the questionnaire project team members were contacted and appointments were requested in order to fill the questionnaire and obtain project documents. Four members from different companies of two projects accepted the interview. Interviews were conducted on the appointed dates at the company offices.

Data from questionnaire and project document were collected and analyzed. Other green building cost studies were also analyzed together with the examined Case studies in order to have a better understanding of cost factors. After analysis of Case studies and other studies are done comparison of the results is examined at the discussion part. Findings of the thesis are shortly explained in conclusion.

3.1. Definition of Case Study

Case study provides data within a specific context which enables the researcher a detailed, complete and in-depth examination. Thomas (2011) defines the Case study as follows: “Case studies are analyses of persons, events, decisions, periods, projects, policies, institutions, or other systems that are studied holistically by one or more method. The Case that is the subject of the inquiry will be an instance of a class of phenomena that provides an analytical frame - an object - within which the study is conducted and which the Case illuminates and explicates”.

Most Cases the research examines a small area or a very limited number of units as the subjects. In some, a single Case or event is selected for the study. Zaidah Z. (2007) states that the examination provides a systematic way of observing the events, collecting data, analyzing information and reporting results over a long period of time. There are a number of advantages of conducting Case studies. First, in a Case study the data is examined within the context of its use whereas in an experiment a phenomenon is isolated from its context. Second, both qualitative and quantitative analyses of the data are utilized regarding variations in terms of intrinsic, instrumental and collective approaches. Third, in-depth examination of the Case not only help to see the real-life environment, but also provides explanations about real-life situations which are not sufficiently captured through survey or experimental search (Aktas, 2013).

Yin (2009) states that the logic of design constitutes as part of a twofold the first form as study Case and the second form as the Case for research. It is stated by Yin (2009) as:

- A Case study is an empirical inquiry that,
- investigates a contemporary phenomenon in depth and within its real-life context, especially when,
- the boundaries between phenomenon and context are not clearly evident.”

- The Case study inquiry,
- copes with the technically distinctive situation in which there will be many more variables of interest than data points, and as one result,
- relies on multiple sources of evidence, with data needing to converge in a triangulating fashion, and as another result,

- benefits from the prior development of theoretical propositions to guide data collection and analysis.

The Case study is a research strategy covering the logic of design, data collection techniques and specific approaches to data analysis (Yin, 2003). In this context, the Case study is neither a data collection method nor a design feature alone (Stoecker, 1991) but a comprehensive research strategy.

3.2. The Case Study as a Research Method

The Case study is a commonly used research strategy in the literature to investigate real life situations and to support decision making. Case study research includes one or more Case studies. Yin (2009) states that there are three types of Case studies that can be used:

(i) Explanatory or causal Case studies, investigate an event and its interrelationships in depth.
(ii) Descriptive Case studies collect information on specific properties of an issue and described in detail.
(iii) Exploratory Case studies are used when the questions is not clear in a new research area.

Yin (2009) explained the relevant conditions for different research methods on the Table 3.1. There are three conditions, namely, the type of research question posed, the extent of control an investigator has over actual behavioral events, and the degree of focus on contemporary as opposed to historical events. These three conditions are related to the five major research methods being discussed: experiments, surveys, archival analyses, histories, and Case studies (Aktas, 2013).

Table 3.1. Relevant situations for different research methods (Yin, 2009).

Method	**Form of Research Question**	**Requires Control of Behavioral Events?**	**Focuses on Contemporary Events?**
Experiment	how, why	Yes	Yes
Survey	who, what, where, how many, how much	No	Yes
Archival Analysis	who, what, where, how many, how much	No	Yes / No
History	how, why	No	No
Case Study	how, why	No	Yes

The most affective factor to determine the research method is to firstly determine the type of research question posed. The basic types of questions are: "who," "what," "where," "how," and "why" questions. As seen on the Table 3.1; "Who", "What" "Where" "How many" and "How much" questions can be used to conduct an archival analysis or a survey. They are being advantageous when the research goal is to describe the event or commonness of a phenomenon or the frequency of outcomes. On the other hand, "how" and "why" questions are questions are more exploratory compared to other questions. Use of Case studies, histories, and experiments are chosen when the questions are "how and "why". This is because such questions deal with links between the events and operations which are needed to be traced over time, rather than prevalence or incidence (Yin, 2009).

In this thesis, the main questions are determined as "how" and "why" since the aim of the study is to show how the project budget is affected by the green building decision. The goal is to explain the decisions of project team during green building implementation. There is no control of events in this study and the main focus is on contemporary events during the whole investigation process.

3.3. Strengths and Weaknesses of Case Study

Siggelkow (2007) explains the major applications of Case studies which are considered as strengths of this type:

(i) Case data provides stronger and more convincing arguments about causal relationships than empirical and theoretical data do. Thus, readers can understand the conceptual phenomena easier with the real-life examples.
(ii) Arguments and motivations supported with real life events rather than theoretical arguments and motivations make the Case more convincing.
(iii) Variety of factors and rich data provided by the real-life Cases expand the perception argument and can inspire for new ideas. In Cases when theoretical knowledge is limited a Case study can provide many sources and tools.

On the other hand, there are a number of weaknesses that Case studies have:

(i) Case studies are generally implemented on a few number of Cases and these Cases may not present the whole population. Thus, Case study results cannot be used for statistical outcomes.
(ii) The problem of ex-post obviousness is a common problem which is defined as the situation that the results of the Case studies may seem obvious to readers.
(iii) It is possible for Case studies to become too detailed which can prevent to generate a useful theory.

Flyvbjerg (2011) explains the different characteristics of Case studies and statistical methods on the table 3.1. Strengths and weaknesses of these research methods are compared on the table. As discussed in the previous chapter, the table supports that the Case study method should be pursued if in depth analysis is needed and statistical method should be used when prevalence of an event or correlations between wide-spread phenomenon are needed.

Table 3.2. Complementarity of Case studies and statistical methods (Flyvbjerg, 2011).

	Case Studies	**Statistical Methods**
Strengths	Depth	Breadth
	High conceptual validity	Understanding how widespread a phenomenon is across a population
	Understanding of context and process	Measures of correlation for populations of Cases
	Understanding of what causes a phenomenon linking causes and outcomes	Establishment of probabilistic level of confidence
	Fostering new hypotheses and new research questions	
Weaknesses	Selection bias may overstate or understate relationships	Conceptual stretching by grouping together dissimilar Cases to get larger samples
	Weak understanding of occurrence in population of phenomena under study	Weak understanding of context, process and causal mechanisms
	Statistical significance often unknown or unclear	Correlation does not imply causation
		Weak mechanisms for fostering new hypotheses

3.4. Requirements of Case Studies

It is important for a research design to prove its quality by meeting certain requirements commonly established in the literature. Since a research design represents a logical set of statements, they can be evaluated by certain logical tests. Research design needs to pass these tests in order to prove the quality of the Case study. Each test deserves explicit attention not only in the beginning of the Case study but throughout the implementation of the Case study. This may result in that design work of Case study to continue after initial plans (Yin, 2009).

Four tests are commonly established in the literature, namely, construct validity, internal validity, external validity and reliability. Table 3.3 which is prepared by Yin (2009), lists the four widely used tests and the recommended Case study tactics, as well as a cross-reference to the phase of research when the tactic is to be used.

Table 3.3. Case study tactics for four design tests (Yin, 2009).

Tests	**Case Study Tactic**	**Phase of Research in which Tactic Occurs**
Construct Validity	Use multiple sources of evidence Establish chain of evidence Have key informants review draft Case study report	data collection data collection composition
Internal Validity	Do pattern matching Do explanation building Address rival explanations Use logic models	data analysis data analysis data analysis data analysis
External Validity	Use theory in single Case studies Use replication logic in multiple Case studies	research design research design
Reliability	Use Cases study protocol Develop Case study database	data collection data collection

Yin (2009) explains the tests in detail:

(i) Construct validity: This first test is especially challenging according to Yin (2009). This test is about the quality of operational measures determined to investigate the Case. In order to meet the test, the investigator must use multiple sources of evidence, establish a chain of evidence, adopt different points of views and have key informants review draft Case study report (Yin, 2009).

(ii) Internal validity: Internal validity is mainly a concern for explanatory Case studies, when an investigator is trying to explain causal connection between events. If the investigator fails to find the correct causal relationship between events, the research design fails to provide internal validity. A clear research frame work, explanation building, pattern matching techniques, rival explanations and use of logical models can help to meet the requirement for a correct casual relationship between events (Aktas, 2013).

(iii) External validity: Yin (2009) states that the third test deals with the problem of knowing whether a study's findings are generalizable beyond the immediate Case study. This test is a major obstacle in doing Case studies since there are common critics that state single Cases cannot offer a basis for generalizing. However, it should be noted that where survey research relies on statistical generalization, Case studies rely on analytical generalization. The theory that researcher established must be tested by replications in second or third Cases and results should be the same in order to meet the requirements of this test (Yin, 2009).

(iv) Reliability: The aim of this test is to minimize the errors and biases in the research. The researcher should be sure that if a later researcher followed the same procedures conducted the same Case study all over again, the findings and conclusions must be the same. Reliability can be provided by transparently document the procedures so that it can be repeated by another researcher (Yin, 2009).

To conclude, four commonly established tests are considered to evaluate quality of a Case study research design. There are various tactics to meet these tests which can be implemented on different stages of a Case study research such as data collection, data analysis and compositional stages. In this thesis following items for each test are done to increase the quality of the research: Construct validity: Multiple sources of evidences are used in the study. Interviews with project members are conducted. Besides the interviews; official project drawings, reports, photographs and LEED certification submission documents are used. Chain of evidence is established between interviews, plans and photographs.

Internal validity: Internal validity is established by explaining the green building implementation and costs according to LEED certification requirements. All Case studies are selected LEED Gold and Platinum certified buildings and the achieved credits are known. Since each LEED credit determines specific green building strategies in detail, the reasons of costs for strategies are obvious. Also, patterns in costs results are searched according to Case conditions.

External validity: Multiple Case studies are selected in order to provide external validity. Additionally, results of statistical research in the literature are compared with the results of this study. Reliability: In order to allow replication of the Case studies, all steps taken in the research are well documented. It is possible for another researcher to follow the same steps.

3.5. Investigated Projects

There are different green building certification systems as discussed in the previous chapter. There are only LEED, BREEAM and DGNB certified buildings in Turkey at the moment. Thus, it is decided to select Case studies among these certifications. The number of certified buildings in Turkey and in the world with these systems are given in the Table 3.4. As seen on the table, it is clear that LEED green building certification system is the most widely used system in Turkey and in the world. Additionally, literature review shows that there are more studies about LEED certification than other certification systems. In order to be able to compare this study with other studies and to provide a more useful result for the construction sector, it is decided to evaluate LEED certified buildings for the Case study.

LEED has different rating systems for different types of buildings as discussed in the previous chapter: New construction and major renovation, existing buildings operation and maintenance, commercial interiors, neighborhood development and homes. Table 3.5 shows the number of projects certified under each certification type. These types of projects have different project conditions and LEED certification system has different guidelines and rating schemes for each these types. Therefore, they are not comparable in terms of green building implementation and related costs. Since most of the projects completed in Turkey are certified under New Construction and Major Renovation, it is decided to select the Case studies among them.

Table 3.4. Number of Buildings Certified by LEED, BREEAM and DGNB (USGBC, 2017).

Certification System	**Number of Certified Buildings in Turkey**	**Number of Certified Buildings in the World**
LEED	171	30.000
BREEAM	49	13.000
DGNB	1	1.280

Table 3.5. Types of LEED Certified Projects in Turkey (USGBC, 2017).

Certification Type	**Number of Certified Projects in Turkey**
New Construction and Major Renovation	127
Existing Buildings Operation and Maintenance	14
Commercial Interiors	16
Neighborhood Development	0
Homes	14

There are different certification levels of LEED as discussed in the previous chapter, namely; LEED Certified, LEED Silver, LEED Gold and LEED Platinum. It can be said that higher the certification level, greener is the building and the effort to achieve LEED certification increases with the level of certification. LEED Platinum certified buildings are the most green buildings compared to other levels. It is decided to evaluate LEED Platinum level certified buildings to conduct a more specific research. Table 3.6 shows the number of certified buildings under LEED New Construction and Major Renovation for each certification level.

Table 3.6. Number of LEED New Construction and Major Renovation Projects (USGBC, 2017).

Certification Level	**Number of Certified Buildings under LEED New Construction and Major Renovation in Turkey**
LEED Certified	8
LEED Silver	18
LEED Gold	89
LEED Platinum	12

The list of 12 LEED-Platinum certified projects in Turkey are given on the Table 3.7 with their certification type, year and score. All projects are newly constructed and most of the LEED Platinum certified new buildings are offices. Some of them are CS (Core&Shell) certified because they contain mainly tenant area. There are some differences in implementation between CS and NC (New Construction) certifications. However, these differences are small and do not prevent to make a fair comparison. The differences between CS and NC certifications are explained in Table 3.8.

In this study, two LEED Platinum certified and two LEED Gold certified projects are selected as Case studies: Ronesans Kucukyali Office Park AB and C Block (LEED-

CS Platinum), Turkish Contractors Association Headquarters (LEED-NC Platinum), Bikur BAB Office (LEED-CS Gold) and Tupras R&D Management Building (LEED-NC Gold).

Table 3.7. LEED Platinum certified office projects in Turkey (USGBC, 2017).

Name	**Location**	**LEED Certificate**	**Level / Year**	**Achieved score out of 110**
Eser Holding Headquarters	Ankara	NC v2009	Platinum / 2011	92
Çimsa Dining Hall	Eskisehir	NC v2009	Platinum / 2016	82
Prokon-Ekon Headquarters	Ankara	NC v2009	Platinum / 2016	89
AND Office	Istanbul	CS v2009	Platinum / 2016	82
42 Maslak Office 2	Istanbul	CS v2009	Platinum / 2014	80
42 Maslak Office 3	Istanbul	CS v2009	Platinum / 2014	84
Ronesans Kucukyali Office Park (AB Block)	Istanbul	CS v2009	Platinum / 2015	82
Ronesans Kucukyali Office Park (C Block)	Istanbul	CS v2009	Platinum / 2015	82
Ronesans Tower Office Building	Istanbul	CS v2009	Platinum / 2014	81
Turkish Contractors Association HQ	Ankara	NC v2009	Platinum / 2014	81
ERKE Green Academy	Istanbul	NC v2009	Platinum / 2013	82
Gaziantep Yesil Ev	Gaziantep	NC v2009	Platinum / 2015	86

Table 3.8. Differences of LEED Core & Shell and New Construction Certification (USGBC, 2017).

Credit Name	**LEED-CS**	**LEED-NC**
SSc.4.2 Alternative Transportation-Bicycle Storage and Changing Rooms	2 points	1 point
SSc.9 Tenant Design and Construction Guidelines	1 point.	N/A
EAc.1 Energy Performance	21 points	19 points
EAc.2 Renewable Energy	4 points	7 points
EAc.5 Measurement and Verification	Includes two credit parts 5.1 for base building, 5.2 for tenant area. Total of 6 points.	3 points.
MRc.1 Building Reuse MRc.3 Materials Reuse	5 points 1 point	4 points 2 points
MRc.6 Rapidly Renewable Materials	N/A	Worth 1 point.
IEQc.3.2 Construction IAQ Management Plan-Before Occupancy	N/A	Worth 1 point.
IEQc.6.1 Controllability of Systems-Lighting	N/A	Worth 1 point.
IEQc.7.2 Thermal Comfort-Verificat	N/A	Worth 1 point.

Ronesans Kucukyali Office Park AB and C Blocks are examined together as one project since they are designed and built together and they are located in the same site. The green building implementation and achieved credits are same in these two buildings.

3.6. Sources of Data

In this thesis, several different resources are utilized to obtain data. First; project documents, reports, forms and drawings are used to gather data. These documents are obtained from the project members after the consent of the clients. Second; interviews with members of project team are made to explore direct observations and gather data which cannot be found in written documents. Team members of projects who are related to green building implementation and budget issues are interviewed.

Most of the project documents related LEED certification were obtained from interviewees during the interview. The project documents received included; floor plans, sections, elevations, site plans, roof plans, 3D renderings, electrical and mechanical drawings, electrical and mechanical equipment list, photographs of the construction, LEED submission forms and reports for each credit, energy and daylight modeling reports, waste management plans, indoor air quality plans, erosion sedimentation and control plans. The documents were obtained via online document sharing tools. There weren't any hardcopy documents obtained, all documents were obtained as soft copies. The documents were organized into each LEED credit to gain better understanding of green building implementation and important documents are given in this thesis fourth chapter.

There are six project team members participated in the study. Four of the interviewees were from the developer companies of the project, two of them were from the contractor companies and one of them was green building consultant. In Tables 3.9, each project and corresponding interviewee information can be seen. In scope of this thesis four face-to-face interviews (two for each project) were carried out in addition to the examination of project documents. Each interviewee had an active role during the building design and construction and had substantial knowledge about green building implementation and related costs. Interviews were done in the company offices and lasted around one and half hours. The questionnaire forms which are prepared specifically for each project were used in order to discuss the LEED credits in order during the interviews. The questionnaire forms included each LEED credit that interviewed project implemented. The information of LEED credits that projects achieved were taken from the USGBC's project directory. Next to each LEED credit the columns for explanation of green building implementation, explanation of related costs and total cost were included.

Green building implementation section included which strategies and practices were implemented for the related LEED credit. It was filled with the information taken from the interviewees and project documents. The information from these sources were combined in the thesis.

Cost items column was filled with the information of implementation items that resulted in a cost increase in terms of labor or materials. This information wasn't available in the provided project documents. Thus, the interviewees and cost documents they had access were the source of the cost items. Material cost increases, labor hours, consultancy fees, certification fees were calculated as items. Most of the items had clear cost calculations. However, some of the cost items were not calculated before and therefore they were calculated by the interviewee during the interview.

Table 3.9. Interviewees that contributed to the study..

Project	**Interviewee**	**Company**	**Title**	**Experience**
Ronesans Kucukyali Office Center	Interviewee 1	Ronesans Real Estate Investment	Project engineer responsible for LEED certification	8 years
	Interviewee 2	Turkeco Consultancy Ltd. Sti.	LEED AP / Consultant	6 years
Turkish Contractors Association Headquarters	Interviewee 3	Mesa Mesken Sanayii A.S.	Head of Technical Office	4 years
	Interviewee 4	Turkish Contractors Association	Deputy Secretary General	15 years
Bikur Office	Interviewee 5	Bikur Yapi	Managing Partner	23 years
Tupras R and D Management Building	Interviewee 6	Ark Construction	Site Architect	7 years

4. CASE STUDIES

The Case study projects are explained in this section of the thesis. All projects are newly constructed buildings. However, Kucukyali Office Park and Bikur Plaza projects are completed as Core & Shell and most of the building area is left empty to be rented. TCA Headquarters and Tupras Building are completely built including interior finishes. Thus, there are slight differences in certification criteria regarding tenant usage. These differences do not affect the green building implementation as they are explained in this chapter.

In this chapter, first, general information is given about the project. The LEED scorecard of the projects are shown to provide a general look to the scores. The implementation of LEED credits is explained in detail for each project. During that, the costs related to credit are separated into three categories: Costs per unit area, costs per project and costs depending the concept architectural project. In the last section, costs in each category and their parameters are defined in more detail and summarized.

4.1. Case 1: Ronesans Kucukyali Office Park

4.1.1. General Information

Ronesans Kucukyali Office Park is developed by Ronesans Real Estate Investment Company. It is located in Kucukyali, Istanbul and contains three office blocks with a total area of 75,000 m^2. The project has achieved LEED - Platinum certification for each building in 2015. It is also the first campus project which is earned LEED Platinum in Turkey and in Europe. The project budget is approximately 60 million U.S. dollars according to LEED submission documents.

Figure 4.1. Outside view of the office.

Three building blocks are located in a site which is 25,000 m^2. The site contains car parking, green area, a pool and plaza areas for pedestrians. The building blocks contain 4 basement floors which are utilized as car parking. The ground floor contains retail area. There are 9 to 12 floors in the blocks which contain office zones. The project team can be seen in Table 4.1 and the site plan is shown in Figure 4.2.

Table 4.1. Project Team of Case 1.

Project Team	**Company**
Architectural Design	A Tasarim Design Office
Mechanical Design	Okutan Engineering
Electrical Design	Ram Engineering
Landscape Design	Dalokay Architecture
General Contractor	Ronesans Construction
Sustainability Consultant	Turkeco Consultancy
Commissioning Agent	Kiklop Engineering

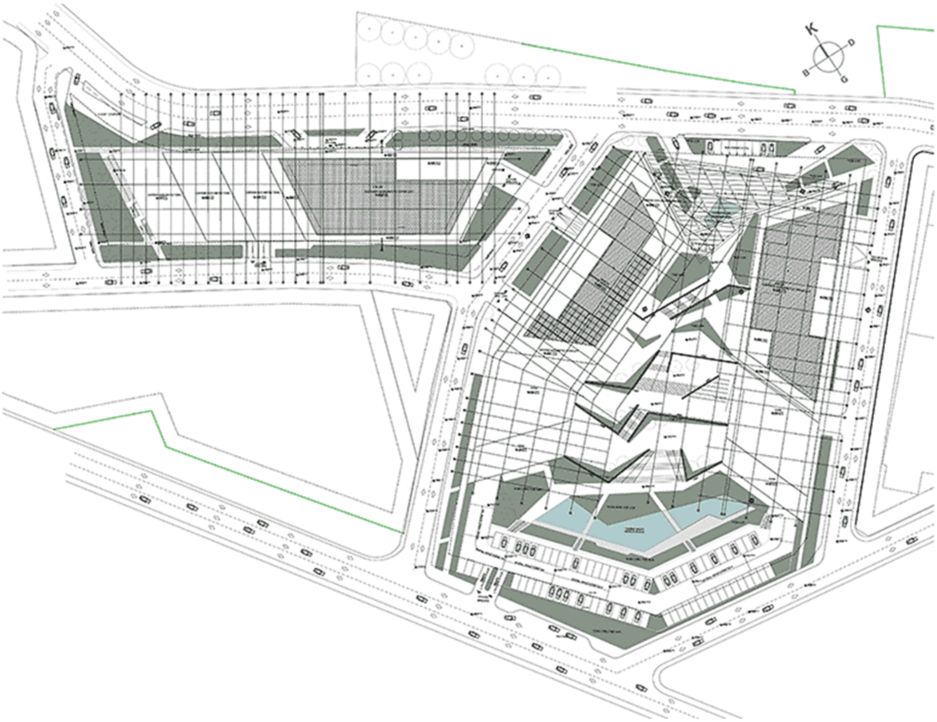

Figure 4.2. Site plan of Case 1.

Figure 4.3. Site 3D view of Case 1.

4.1.2. Green Building Implementation

The project utilized many different green building strategies. These strategies are decided in the early design aiming to maximize LEED points and minimize the initial costs. The project achieved 82 points out of 110 points of LEED. The list of achieved LEED criteria is given in Table 4.1.2. Some criteria of LEED are prerequisites and they are mandatory for every level of certification. Criteria that the project implemented are explained in detail in this chapter under each category. Requirements are shortly described according to USGBC (2009) LEED Reference Guide and implementation to fulfil the requirement is explained according to project documents and interviews with project responsibles.

Table 4.2. LEED scorecard of Case 1.

Sustainable Sites		**Possible Points**	**Achieved Points**
Prereq 1	Construction Activity Pollution Prevention	Prerequisite	
Credit 1	Site Selection	1	1
Credit 2	Development Density and Community Connectivity	5	5
Credit 3	Brownfield Redevelopment	1	0
Credit 4.1	Alternative Transportation-Public Transportation Access	6	6
Credit 4.2	Alternative Transportation-Bicycle Storage and Changing Rooms	2	2
Credit 4.3	Alternative Transportation-Low-Emitting and Fuel-Efficient Vehicles	3	3
Credit 4.4	Alternative Transportation-Parking Capacity	2	2
Credit 5.1	Site Development-Protect or Restore Habitat	1	1
Credit 5.2	Site Development-Maximize Open Space	1	1
Credit 6.1	Stormwater Design-Quantity Control	1	1
Credit 6.2	Stormwater Design-Quality Control	1	0
Credit 7.1	Heat Island Effect-Non-roof	1	1
Credit 7.2	Heat Island Effect-Roof	1	1
Credit 8	Light Pollution Reduction	1	0
Credit 9	Tenant Design and Construction Guidelines	1	1

Table 4.2. LEED scorecard of Case 1 (cont.).

Sustainable Sites		**Possible Points**	**Achieved Points**
Water Efficiency			
Prereq 1	Water Use Reduction-20% Reduction	Prerequisite	
Credit 1	Water Efficient Landscaping	4	2
Credit 2	Innovative Wastewater Technologies	2	2
Credit 3	Water Use Reduction	4	4
Energy and Atmosphere			
Prereq 1	Fundamental Commissioning of Building Energy Systems	Prerequisite	
Prereq 2	Minimum Energy Performance	Prerequisite	
Prereq 3	Fundamental Refrigerant Management	Prerequisite	
Credit 1	Optimize Energy Performance	21	12
Credit 2	On-Site Renewable Energy	4	0
Credit 3	Enhanced Commissioning	2	2
Credit 4	Enhanced Refrigerant Management	2	2
Credit 5.1	Measurement and Verification-Base Building	3	3
Credit 5.2	Measurement and Verification-Tenant Submetering	3	3
Credit 6	Green Power	2	0
Materials and Resources			
Prereq 1	Storage and Collection of Recyclables	Prerequisite	
Credit 1	Building Reuse-Maintain Existing Walls, Floors, and Roof	5	0
Credit 2	Construction Waste Management	2	2
Credit 3	Materials Reuse	1	0
Credit 4	Recycled Content	2	2
Credit 5	Regional Materials	2	2
Credit 6	Certified Wood	1	1
Indoor Environmental Quality			
Prereq 1	Minimum Indoor Air Quality Performance	Prerequisite	
Prereq 2	Environmental Tobacco Smoke (ETS) Control	Prerequisite	
Credit 1	Outdoor Air Delivery Monitoring	1	1
Credit 2	Increased Ventilation	1	1
Credit 3	Construction Indoor Air Quality Management Plan-During Construction	1	1
Credit 4.1	Low-Emitting Materials-Adhesives and Sealants	1	1
Credit 4.2	Low-Emitting Materials-Paints and Coatings	1	1
Credit 4.3	Low-Emitting Materials-Flooring Systems	1	1
Credit 4.4	Low-Emitting Materials-Composite Wood and Agrifiber Products	1	0

Table 4.2. LEED scorecard of Case 1 (cont.).

Sustainable Sites		**Possible Points**	**Achieved Points**
Credit 5	Indoor Chemical and Pollutant Source Control	1	1
Credit 6	Controllability of Systems-Thermal Comfort	1	0
Credit 7	Thermal Comfort-Design	1	1
Credit 8.1	Daylight and Views-Daylight	1	1
Credit 8.2	Daylight and Views-Views	1	1
Innovation and Design			
Credit 1	Innovation in Design: Specific Title	5	5
Credit 2	LEED Accredited Professional	1	1
Regional Priority			
Credit 1	Regional Priority: Specific Credit	4	4
Total Points		**110**	**82**

4.1.2.1. Sustainable Sites. Sustainable sites category deals with the issues related to site location, its relation with surroundings and how the open space is designed.

4.1.3. Prerequisite 1, Construction Activity Pollution Prevention

The intent of this prerequisite is to reduce pollution from construction activities by controlling soil erosion, waterway sedimentation and airborne dust generation. An Erosion and Sedimentation Control (ESC) Plan is created and implemented for all construction activities. The plan conformed to the erosion and sedimentation requirements of the U.S. 2003 EPA Construction General Permit (USGBC, 2009).

The site is closed with perimeter fencing. Perimeter fencing is implemented without any holes under or between to avoid any soil or dust escaping from the site. Geotextile is buried under the fencing to avoid soil flow after heavy rain. Photographs of the fencing can be seen in Figure 4.4 and Figure 4.5.

Figure 4.4. Installation of fencing of Case 1.

Figure 4.5. Site fencing of Case 1.

Sedimentation of sewers and receiving streams are prevented by implementing sediment traps for surface rain water. The water is collected and filtered in these traps before pumped to the sewers. The photograph of the sediment trap is given in Figure 4.6.

Figure 4.6. Sediment trap of Case 1.

In order to prevent dust and particulate matter pollute the surrounding the wheels of leaving vehicles are cleaned. A washing area is designed for the trucks as shown in the Figure 4.7. All leaving trucks had to go through this washing area before leaving the site. Sediment trap is designed next to the washing area in order to prevent sedimentation of sewers. These strategies are included in the contractor's requirements and created additional costs.

Figure 4.7. Truck washing area of Case 1.

4.1.4. Credit 1, Site Selection

The intent of this credit is to avoid the development of inappropriate sites and reduce the environmental impact from the location of a building on a site. In order to achieve this credit, the site shouldn't qualify one of the below options (USGBC, 2009):

- Prime farmland,
- Previously undeveloped land whose elevation is lower than 5 feet above the elevation of the 100-year flood.
- Land specifically identified as habitat for any species.
- Within 100 feet of any wetlands,
- Previously undeveloped land that is within 50 feet of a water body, defined as seas, lakes, rivers, streams and tributaries which support or could support fish.
- Land which prior to acquisition for the project was public parkland.

The site of the project was used as warehouse before and it doesn't qualify any of these options by itself. The credit is taken without any effort.

4.1.5. Credit 2, Development Density and Community Connectivity

The intent of this credit is to channel development to urban areas with existing infrastructure, protect green fields and preserve habitat and natural resources. The site must be previously developed site and located in a neighborhood with a minimum building floor area to site ratio of one and half (1.5) (USGBC, 2009). A map of surroundings is prepared in order to show the building density in the community. Each number on the map presents a building block. The approximate floor and site area of each building block is documented. The map can be seen in Figure 4.8.

4.1.6. Credit 4.1, Alternative Transportation - Public Transportation Access

The intent of this credit is to reduce pollution and land development impacts from automobile use. The project must be located within 800 meters of a subway or railway station or 400 meters of a bus station (USGBC, 2009). The project complied with this credit since it is located on a main district and bus stations are located in close distance. A map showing the bus stops near the site is prepared as shown in Figure 4.9.

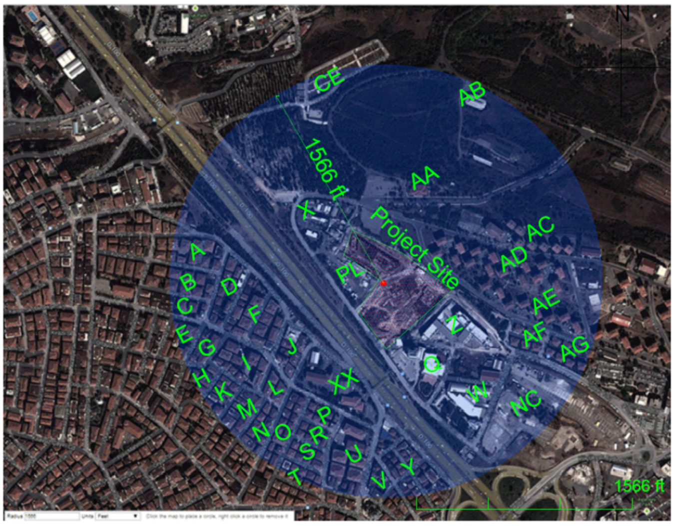

Figure 4.8. Development density map of Case 1.

Figure 4.9. Transportation map of Case 1.

4.1.7. Credit 4.2, Alternative Transportation-Bicycle Storage and Changing Rooms

The aim of this credit is to increase the bicycle usage by providing facilities. Bicycle racks for 5% or more of all building users (measured at peak periods), and shower and changing facilities in the building for 0.5% of employee is designed to achieve this credit (USGBC, 2009). The bicycle racks are put on the open space next to the office entrances. Shower and changing facilities are open to all employee and located in the basement floors. Implementation of these facilities resulted in additional costs per unit area. It is estimated that 2,000 people will work in the project. Thus, 65 secure bicycle racks and 25 shower facilities are provided.

4.1.8. Credit 4.3, Alternative Transportation-Low-Emitting and Fuel-Efficient Vehicles

The aim of this credit is to increase the usage of environmentally preferable cars. 5% of the carpark which is closest to the building entrances are reserved for green cars. Green cars are defined as low-emitting and fuel-efficient cars which include electric cars and hybrid cars (USGBC, 2009). The reserved spaces are indicated with signage as shown in the figure 4. The capacity of total carpark in the project is 790. 40 spaces in various building entrances are reserved for green cars. The credit is with small additional cost of signage preparation.

4.1.9. Credit 4.4, Alternative Transportation - Parking Capacity

The aim of this credit is to decrease the usage of private vehicles and increase the alternative transportation methods. Thus, the capacity of car parking is limited by local regulations. The number of provided car park cannot exceed the minimum number given in the local regulation (USGBC, 2009). The car parking regulation of Istanbul requires one car park for 50 m^2 of office space. The project office area is 46,300 m^2 and 926 (46300/50) spaces are allowed. The project has only 790 parking space. The credit is achieved without additional costs but it was depended on the concept architectural project.

Figure 4.10. Reserved parking signage of Case 1.

4.1.10. Credit 5.1, Site Development-Protect or Restore Habitat

The aim of this credit is to provide habitat and promote biodiversity by increasing native or adapted vegetated areas in the project. 20% of total site area (including building footprint) should be landscaped with vegetation as a rule (USGBC, 2009). The partial roof of basement floors is utilized as green roofs to provide a better experience in terraces. The project site is 25,600 m^2 and it is designed to have 6,200 m^2 of green landscape and 1,250 m^2 of vegetated roof which results 29% vegetated area. The plants are selected from native to the local climate or adapted species by the landscape designer. The green roof implementation resulted in additional costs per unit area.

4.1.11. Credit 5.2, Site Development-Maximize Open Space

The aim of this credit is to open space for the building users. 20% of total site area (including building footprint) should be landscaped or open to pedestrian access (USGBC, 2009). The project site has 11,200 m^2 of open space containing green and pedestrian area which is 41% of total site. The credit is achieved without additional costs but it was depended on the concept architectural project.

4.1.12. Credit 6.1, Storm Water Design - Quantity Control

The credit aims to prevent disturbance of natural hydrology by increasing on-site infiltration, reducing impervious cover and eliminating contaminants and pollution from stormwater surface runoff (USGBC, 2009). A stormwater management plan is implemented that results in a 25% decrease in the volume of stormwater surface runoff from the two-year 24-hour design storm compared to previous condition of the site. The previous condition of the site had impervious cover (hardscape) of 90% of total site. After landscaping in the project the impervious cover on the site decreased to 60%. As a result, the water runoff to sewers are reduced approximately 25%. The credit is achieved without additional costs but it was depended on the concept architectural project.

4.1.13. Credit 7.1, Heat Island Effect-Non-roof

Heat island effect is the phenomena of thermal difference between developed and undeveloped areas. The intent of this credit is to reduce heat islands to minimize impacts on microclimates and human and wildlife habitats (USGBC, 2009). One of the reasons of the heat island effect is the asphalt surfaces. Asphalt absorbs heat from sun and results in temperature increase in surroundings. In order to avoid this effect, LEED requires that 50% of car park should be underground or shaded. 80% of carpark is located under the buildings in the project. Thus, the credit is achieved without additional costs but it was depended on the concept architectural project.

4.1.14. Credit 7.2, Heat Island Effect-Roof

The intent of this credit is to reduce heat islands to minimize impacts on microclimates and human and wildlife habitats. One of the reasons of the heat island effect is the materials used on the building roofs (USGBC, 2009). Materials with low SRI

(Solar Reflectance Index) absorb much of the heat and this is resulting heating of the building and surroundings. In order to avoid this situation, materials which have SRI values higher than 78 or green roofs should be installed on the roof. In this projects, green roofs and white colored roofing membrane cover materials are implemented on the roof. White colored roofing membrane has an SRI of 102. This implementation does have costs per unit area of green roof and membrane.

4.1.15. Credit 9, Tenant Design and Construction Guidelines

Most of the office spaces are to be rented in the project. It is important how tenants fit-out these spaces in terms of sustainability. In order to support the green features of the building it is expected that tenants follow a set of requirements (USGBC, 2009). Thus, a tenant design and construction guideline and green lease for tenants are prepared. Green lease contains mandatory items of LEED which tenants must perform similar to the prerequisite items discussed in this section. The guideline is not mandatory but it instructs the tenants how to design their space in a more sustainable way. The guideline includes all the categories in LEED such as water efficient, energy efficiency and indoor environmental quality. This credit didn't result in additional cost. This category evaluates the buildings domestic and landscaping water consumption.

4.1.16. Prerequisite 1, Credit 2 and Credit 3, Water Use Reduction

The intent of this credit is to reduce the domestic water consumption of the building. Consumption calculations are based on occupant usage and include only the following fixtures: water closets, urinals, lavatory faucets, showers and kitchen sinks (USGBC, 2009). The baseline values are taken according to U.S. Energy Policy Act of 1992 fixture performance requirements. The project performed 49% better than the baseline by selecting low consuming fixture equipment. The table 4.3 shows the consumption values and selected equipment. The project complies with the prerequisite, credit 2 and credit 3 by choosing these water fixtures. These fixtures can be found in the Turkish market and there is not a significant cost premium.

Table 4.3. Water fixtures of Case 1.

Fixture Type	Baseline Consumption Value (EPA, 2009)	Installed Consumption Value	Unit	Brand	Model
Water Closets	6	2.50 - 4.00	liter/flush	VITRA	PAN MATRIX - DUAL
Lavotaries	2	2	liter/cycle	VITRA	AQUASEE 12 secs auto-controlled
Urinal	4	1	liter/flush	VITRA	MATRIX
Shower Head	9.5	6	liter/min	VITRA	ISTANBUL
Kitchen Sink	8.5	6	liter/min	VITRA	AQUASEE

4.1.17. Credit 1, Water Efficient Landscaping

The intent of this credit is to reduce water consumption for landscape irrigation at least by 50% compared to conventional landscaping in the region. In order to achieve this credit landscape designer of the project selected low water consuming plants (USGBC, 2009). The landscape contains mainly trees, shrubs and flowers. No turf grass is installed in the project which has the highest consumption value and most commonly used plant. Instead of turf grass, natural ground cover found in the region is implemented. The list of plants chosen in the project is shown in the Table 4.4. Automated drip irrigation system is implemented in the project instead of conventional sprinkler system. Drip irrigation is assumed to be 40% more efficient than sprinklers. The selection of these plants do not create any additional costs. However, drip irrigation system has an additional cost per unit area implemented.

Table 4.4. Plants selected in Case 1.

Local Plant Name	**Latin Name**
Dogu Karadeniz Göknari	Abies nordmanniana
Gülibrisim	Albizzia julibrissin
Kirmizi Akçaagaç)	Acer rubrum
Erguvan	Cercis siliquastrum
Gümüsi Ihlamur	Tilia tomentosa
Süs Kirazi	Prunus serrulata
Pampas Otu	Cortederia selloana
Yayilici ardiç	Juniperus horizonta
Defne	Laurus nobili
Çali Hanimeli	Lonicera nitida
Sakayik	Paeonia suffriticosa
Bodur pitos	Pittosporum tobira
Zeytin	Olea europaea

4.1.17.1. Energy and Atmosphere. Energy and Atmosphere category includes credits about maximizing energy efficiency, renewable energy production, energy monitoring and depletion of ozone layer.

4.1.18. Prerequisite 1 and Credit 3, Commissioning of Building Energy Systems

Commissioning process ensures that energy consuming systems are installed and calibrated correctly to perform according to owner's project requirements and as it is designed. Commissioning reduces inefficiencies, energy consumption and contractor callbacks. It provides better system documentation and verification for the owner and building management. Commissioning is conducted by a third party company contracted directly by the owner and not included in the project design and construction team (USGBC, 2009).

In this project, an external commissioning company was present from early design to the occupation of the building. All process is reviewed by this company as a third eye and reports are prepared to avoid any deficiency in the future. Also, training and system manual are prepared for the building management personnel. This credit created additional cost since a third party company must be hired for the job.

4.1.19. Prerequisite 2, Credit 1, Energy Performance

This is the most important credit of the LEED certification with a total available points of 21. The intent of the credit is to establish the level of energy efficiency for the proposed building and systems to reduce environmental and economic impacts associated with excessive energy use. The energy efficiency of the building is measured by doing building energy modeling (USGBC, 2009).

Building energy modeling is basically the physics-based calculation of energy consumption of a building. It is a multi-use tool for building energy efficiency. It is mainly used to examine energy efficiency before the building is constructed and research ways to improve efficiency in design. Green building certifications require modeling to determine the energy efficiency of a building compared to a standard. LEED uses ASHRAE 90.1-2007 Appendix G standard as the baseline in modeling (USGBC, 2009).

Energy modeling is done by various software available in the market. Energy modeling uses information inputs of climate; building envelope; internal gains from lighting, equipment, and occupants; heating, cooling, and ventilation systems; schedules of occupants, equipment, lighting and renewable energy production. There are two models for LEED certification; 1) Proposed model, the designed project with planned properties 2) Baseline model, the virtual building with properties identified according to ASHRAE 90.1-2007. Some inputs such as envelope, mechanical systems, lighting are determined according to ASHRAE 90.1-2007 in the baseline where some inputs such as climate, schedules and process equipment are the same as proposed model. The architecture of the baseline is modeled identical except the external sun shading devices. However, the baseline model is rotated 4 times in every direction so the orientation of the proposed building does have an effect on the results. As a result, the difference between the models shows holistic efficiency of the architectural design, building envelope materials, mechanical systems and lighting. Annual energy consumption of all models are converted into costs by multiplying local electricity and natural gas prices to obtain the final result for LEED.

The LEED certification mandates a minimum of 10% efficiency by cost. For every 2% incremental increase in the efficiency the project gets an extra point. LEED points for different energy efficiency levels are shown in Table 4.5. The building achieved 30% improvement and earned 12 points.

Ronesans Kucukyali Office contains three blocks. Two of them (A and B Blocks) are attached to each other in the basement level. Therefore, two energy models, C Block and A-B Blocks are conducted. The models are done using Design Builder v3.2.0.07 software. Designbuilder is a software based on the EnergyPlus modeling algorithm which is released by U.S. Department of Energy.

The architecture of baseline and proposed models are identical except the proposed model does have horizontal sun shading devices around the windows. These sun shading devices block a large amount of solar heat during the midday decrease the cooling loads. Baseline is modeled without shading devices. The 3D model view of the buildings can be seen in Figure 4.11 and Figure 4.12. The pink parts on the figures are the sun shading devices. The proposed model is mainly facing south. The baseline building is rotated for 0, 90, 180 and 270 degrees and average results are calculated.

Table 4.5. LEED points vs. Energy Efficiency (USGBC, 2009).

New Buildings	Points (CS)
12%	3
14%	4
16%	5
18%	6
20%	7
22%	8
24%	9
26%	10
28%	11
30%	12
32%	13
34%	14
36%	15
38%	16
40%	17
42%	18
44%	19
46%	20
48%	21

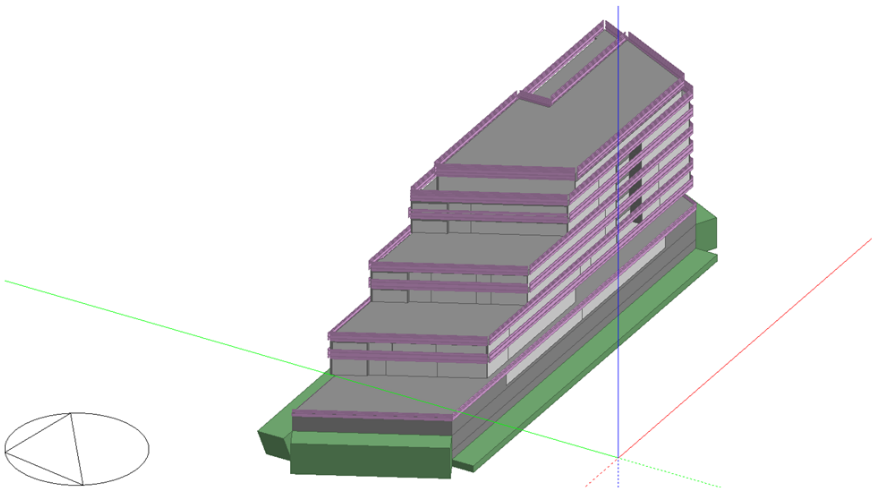

Figure 4.11. C Block Model View of Case 1.

The building envelope thermal properties are designed to increase energy efficiency. The thermal properties of the project compared to ASHRAE 90.1-2007 baseline values can be seen in Table 4.5. Thermal conductance of a material is defined with its overall heat transfer coefficient (U-value). The lower the U-value, the less is the heat transfer through the material. This means lower U-values increase energy efficiency in most of the Cases. Window glass has a U-value and Solar Heat Gain Coefficient (SHGC). SHGC is expressed as a number between 0 and 1. The glass with lower SHGC transmits less solar energy inside the building. In sunny climates SHGC value has a significant impact on cooling loads.

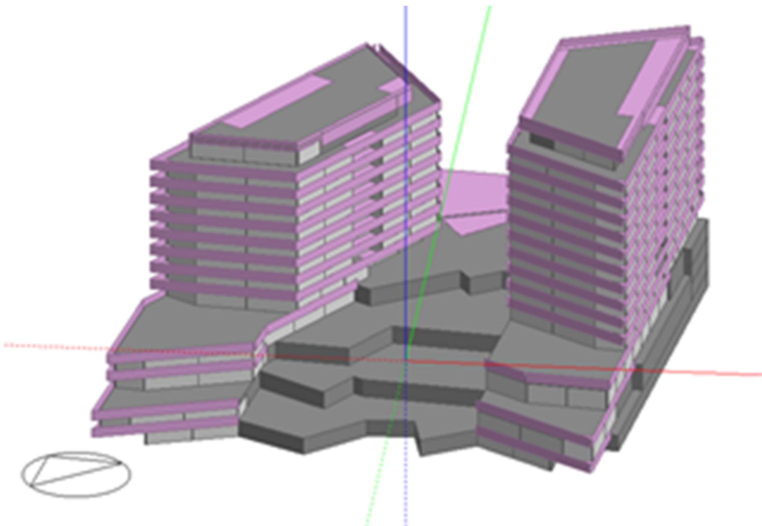

Figure 4.12. A-B Block Model View of Case 1.

The mechanical design is one of the most important aspect in energy efficiency. The HVAC system of the proposed buildings is modeled using based on mechanical drawings and mechanical project report provided by mechanical group. Boilers are designed to meet the heating energy demand of the proposed buildings. Design loop inlet/outlet water temperatures are 85/65 C. Thermal efficiency of the boilers (COP - Coefficient of Performence) is 0.935. As a fuel type natural gas is used.

Air cooled chillers are designed for cooling. Design loop inlet/outlet water temperatures are 6/11 C. COP of the chillers is 3,3. According to function of the zones different heating cooling distribution systems are used. 4-piped Fan Coil system is used office, meeting rooms and circulations. Unitary Equipment is used in technical areas, café, restaurant and gym. The common areas (elevator shaft, and WC) are conditioned and served with fresh air by one air handling unit. Every office floor contains its own

Table 4.6. Comparison of Thermal Properties of Case 1.

	Proposed		**Baseline (ASHRAE, 2009)**	
Building Element	U Factor (W/m^2 K)		U Factor (W/m^2 K)	
Roof	0.263		0.273	
Exterior Wall	0.312		0.365	
Ground Floor	0.338		0.791	
Window	1.400	0.258 SHGC	3.410	0.250 SHGC

air handling unit for ventilation.

All modeling requirements for calculating baseline building performance based on ASHRAE- 90.1 2007. The type of the building is nonresidential and more than 5 floors or > 14.000 m^2, so the System type of the baseline building is 7- VAV (Variable Air Volume) with reheat. The fan control is VAV, cooling type is chilled water and heating type is hot-water fossil fuel boiler. Equipment capacities are oversized 15% for cooling, 25% for heating. Supply and return fans are operated continuously whenever spaces are occupied. Minimum outdoor air ventilation rate is same with proposed building. Air economizer is included in baseline HVAC system. Economizer High-limit shutoff is 24 C0 for 3C climate zone. Supply air to room temperature difference is 11C for baseline model. Exhaust air energy recovery doesn't include in baseline model because cooling climate zone is 3C. Hot water supply/return temperatures are modeled as 82/54 C0; chilled water supply/return temperatures are modeled as 6,7/13 C.

The lighting power density of the building is reduced by selecting LED lighting as much as possible. The lighting power densities of the proposed model and baseline model according to ASHRAE 90.1-2007 can be seen in Table 4.7. Figure 4.13 shows the annual energy consumption results of different load types. Significant improvement is achieved in heating and fans section with almost 50% improvement. The consumption of cooling and lighting is only improved around 10% but they constitute a smaller portion of total consumption. Consumption of pumps are higher in the proposed model because the building contains more pumps than the baseline Case.

Table 4.7. Comparison of Lighting Power Densities of Case 1.

Zone Name	**Proposed Model Lighting [W/m^2]**	**Baseline Model Lighting [W/m^2]**
CARPARK	2.28	2
KITCHEN	10	13
TECHNICAL ROOM	7	16
CIRCULATION	6	6
MEETING ROOM	11	14
GYM	8	10
WC	6	10
CHANGING ROOM	5	6
RESTAURANT	12	15
OFFICE	9	12
MECHNICAL ROOM	5.61	16
DINING ROOM	10	10
ELEVATOR SHAFT	5.81	6
FLOOR GARDEN	6	6
CAFE	12	15

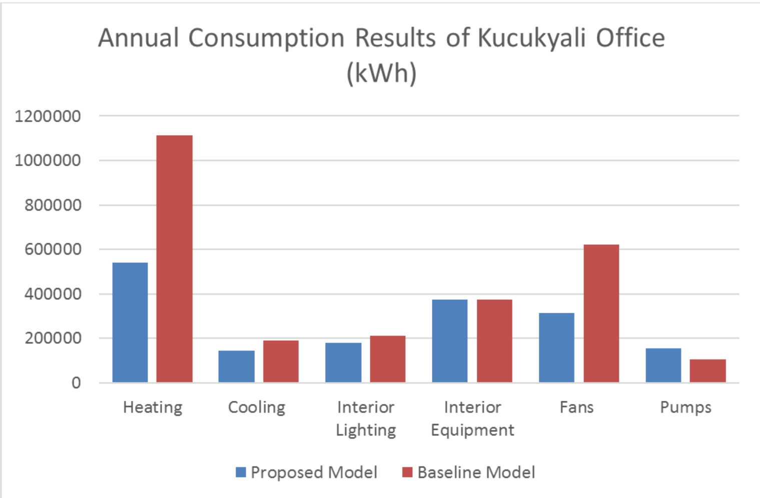

Figure 4.13. Detailed Modeling Results of Case 1.

Final results show that both of the proposed buildings are 30% more cost efficient than the baseline buildings. Table 4.7 shows the consumption values and costs of proposed and baseline buildings. Therefore, the project achieved 12 points out of 21 points. There is an interesting point to mention in this Case. Even though the size and architecture of the building blocks are different from each other, they achieved the same score because they had the same type of façade design, thermal envelope and

HVAC systems.

Table 4.8. Energy Modeling Results of Case 1.

A-B Block				
	Proposed Electricity	**Proposed Natural Gas**	**Baseline Electricity**	**Baseline Natural Gas**
Annual Consumptions (kWh)	2.619,731	375.61	3.574,617	1.094,356
Energy Costs ($)	261.973	14.273	357.461	41.585
Improvement by cost	30.12%			
C Block				
	Proposed Electricity	**Proposed Natural Gas**	**Baseline Electricity**	**Baseline Natural Gas**
Annual Consumptions (kWh)	1.293,728	515.237	1.634.210	1.318,729
Energy Costs ($)	129.372	19.579	163.421	50.111
Improvement by cost	30.24%			

The costs related to this credit is mainly depended on the concept design. Besides that, energy modeling service cost is fixed.

4.1.20. Prerequisite 3 and Credit 4, Refrigerant Management

The intent of this credit is to reduce stratospheric ozone depletion caused by the use of chlorofluorocarbon (CFC)-based refrigerants in building air conditioning systems. LEED has a calculation method to find the depletion impact of the building. The type and amount of refrigerant gas of the installed systems are entered in this calculation. In this project, R-134A and R-410A types of refrigerant gases are used and they are compliant with the certification. There is not any additional costs for this credit (USGBC, 2009).

4.1.21. Credit 5, Measurement and Verification

The intent of this credit is to maintain the designed building energy efficiency over time during the building life by monitoring the energy consumption regularly. A measurement and verification plan is prepared for the project. Metering equipment to measure energy use of cooling, heating and other electrical systems are installed on each tenant space and common areas. These meters are connected to a central automation system which monitors and reports the consumption results regularly. The performance of these systems are compared with predicted performance and broken down by component or system as appropriate. Any deficiencies will be investigated by the building management. Evaluate energy efficiency by comparing actual performance to baseline performance (USGBC, 2009).

Metering equipment and automation system was already planned in concept stage in this project. Thus, the costs are depended on the concept design.

<u>4.1.21.1. Materials and Resources.</u> Materials and resources category includes credits is mainly related to production construction materials and recycle opportunities.

4.1.22. Prerequisite 1, Storage and Collection of Recyclables

The aim of this prerequisite is to reduce the waste generated by building occupants that is hauled to and disposed of in landfills by providing recycle bins. Easily-accessible areas for all building users are designed for the collection and storage of recycle materials. The recycle bins are for paper, glass, plastics and metals (USGBC, 2009). The bins are located on the common areas next to elevators on every floor.

Table 4.9. Explanation of ozone depletion impact explanation (USGBC, 2009).

Imperial units LCGWP + LCODP X $10^2 \leq 100$	**Metric units** LCGWP + LCODP X $10^2 \leq 13$
Calculation definitions for LCGWP + LCODP X $10^2 \leq 100$ (Imperial units)	Calculation definitions for LCGWP + LCODP X $10^2 \leq 13$ (Metric units)
LCODP = [ODPr x (Lr x Life +Mr) x Rc]/Life	LCODP = [ODPr x (Lr x Life +Mr) x Rc]/Life
LCGWP = [GWPr x (Lr x Life +Mr) x Rc]/Life	LCGWP = [GWPr x (Lr x Life +Mr) x Rc]/Life
LCODP: Lifecycle Ozone Depletion Potential (lb CFC 11/Ton-Year)	LCODP: Lifecycle Ozone Depletion Potential (kg CFC 11/kW/year))
LCGWP: Lifecycle Direct Global Warming Potential (lb CO 11/Ton-Year)	LCGWP: Lifecycle Direct Global Warming Potential (kg CO/(kW/year))
GWPr: Global Warming Potential of Refrigerant (0 to 12,000 lb CO/lbr)	ODPr: Ozone Depletion Potential of Refrigerant (0 to 0.2 kg CFC 11/kg r)
ODPr: Ozone Depletion Potential of Refrigerant (0 to 0,2 lb CFC 11/lbr)	GWPr: Global Warming Potential of Refrigerant (0 to 12,000 kg CO/kg r)
Lr: Refrigerant Leakage Rate (0.5% to 2.0%; default of 10% unless otherwise demonstrated)	Lr: Refrigerant Leakage Rate (0.5% to 2.0%; default of 2% unless otherwise demonstrated)
Mr: End-of-life Refrigerant Loss (2% to 10%; default of 10% unless otherwise demonstrated)	Mr: End-of-life Refrigerant Loss (2% to 10%; default of 10% unless otherwise demonstrated)
Rc: Refrigerant Charge (0.5 to 5.0 lbs of refrigerant per ton of gross ARI rated cooling capacity)	Rc: Refrigerant Charge (0.065 to 0.65 kg of refrigerant per kW of ERI rated or Eurovent Certified cooling capacity)
Life: Equipment Life (10 years; default based on equpment type, unless otherwise demonstrated)	Life: Equipment Life (default based on equpment type, unless otherwise)

Table 4.10. Calculation of ozone depletion impact of Case 1 (USGBC, 2009).

HVAC&R Equipment Type	**N**	**Q (tons)**	**Refrigerant**	**GWPr**	**ODPr**	**Rc (lb/ton)**	**Life (yrs)**	**Lr (%)**	**Mr (%)**	**LCGWP**	**LCODP X10^5**	**Impact per ton**	**Impact Total**
Screw Chiller	3	335	R-134a	1.320	0	1.19	23	2	10	38	0	38	38.190
Split AC or Heat Pump	4	1.99	R-410A	1.890	0	4.2	15	2	10	212	0	212	1.688
Split AC or Heat Pump	1	1.42	R-410A	1.890	0	1.4	15	2	10	71	0	71	101
Split AC or Heat Pump	1	3.98	R-410A	1.890	0	4.5	15	2	10	227	0	227	903
	Total	1.018				Average refrigerant impact per ton						40	40.882

Building management collects these bins every night and transfers to storage areas in the basements. Recyclable waste collection of the local municipality occurs twice a week. Recycling storage areas are located in basement of the buildings with a total area of 100 m^2.

4.1.23. Credit 2, Construction Waste Management

The intent of this credit is to reduce construction waste disposed in landfills and recycle or reuse materials as much as possible. A construction waste management plan is developed and implemented which identifies the measures taken in order to divert waste from disposal (USGBC, 2009).

The plan includes detailed measures to minimize the creation of construction and demolition waste on the project site and recycle and/or salvage non-hazardous construction, demolition, and land clearing debris. Construction waste management plan is prepared by LEED consultant and contractor.

As a result, the project diverted 86% of construction waste from landfill and delivered to recycle facilities. Waste types delivered to the recycling are steel, metals, concrete, paper and plastic packages. Recyclable materials are separated on the site and delivered to the recycling facilities by municipality. Thus, there aren't additional costs for this credit.

4.1.24. Credit 4, Recycled Content

The intent of this credit is to reduce impacts from extraction and manufacturing process of virgin materials. Production of materials can include recycled content from pre-consumer or post-consumer material. Post-consumer material is defined as waste material which can no longer be used for its intended purpose. Pre-consumer material is defined as material diverted from the waste stream during the manufacturing process. The project must select materials with recycled content for at least 20% of all construction materials in the project based on cost (USGBC, 2009).

Typically, new rebar used in reinforced concrete structure are produced from scrap iron collected from the region. It does have around 95% post-consumer content. Thus, for the reinforced concrete structures this credit is achieved without any costs. Additionally, in this project aluminum sun shading devices located on the building façade contain 22% pre-consumer content according to aluminum manufacturer. Manufacturer letters and explanations are documented for LEED certification. As a result, construction materials achieved 33% recycled content.

4.1.25. Credit 5, Regional Materials

This credit aims to select building materials and products that are extracted and manufactured within the region (800 km distance from the project site) in order to reduce negative impacts of material transportation. A minimum of 20%, based on cost, of the total construction materials value should be regional (USGBC, 2009). In this project, most of the construction materials are manufactured within 800 km. concrete and stone is manufactured within 800 km. Manufacturer letters and explanatory documents are used for LEED documentation. As a result, 56% of all construction materials are regional.

4.1.26. Credit 6, Certified Wood

Environmentally responsible forest management is encouraged in this credit. 50% based on cost of wood-based materials and products should be certified in accordance with the Forest Stewardship Council's (FSC) principles and criteria. FSC certification of forests ensures that wood is harvested from well managed forests that provide environmental, social and economic benefits. Wood products can be included in structural framing and general dimensional framing, flooring, sub-flooring, wood doors and finishes (USGBC, 2009).

In this project, main wood products are doors and coverings in the reception area. These are purchased from companies that work with FSC certified forests. The FSC certification proof of installed materials are requested from the companies and documented for LEED certification. As a result, 69% of all wood products used in the building is FSC certified. FSC certified wood products have a cost premium which resulted a slight cost increase.

4.1.26.1. Indoor Environmental Quality. This category includes measures related to indoor air quality and occupant comfort.

4.1.27. Prerequisite 1 and Credit 2, Ventilation

The intent of this credit is to ensure that sufficient outdoor air ventilation is provided in the building zones to improve air quality, occupant comfort, well-being and productivity. The projects shall provide 30% above the minimum rates required by ASHRAE 62-1 2007 standard (USGBC, 2009). The mechanical ventilation systems and air handling equipment of the project are designed according to this requirement from the early design. Thus, no additional costs are associated with the credit.

4.1.28. Prerequisite 2, Environmental Tobacco Smoke Control

This prerequisite aims to prevent exposure of building occupants, indoor surfaces and ventilation air distribution systems to tobacco smoke. In order to comply with the credit smoking is prohibited in all areas inside the building similar to the Turkish regulations. Additionally, the prerequisite requires smoking prohibition outside the building within 8 meters of entries, outdoor air intakes and operable windows (USGBC, 2009). In order to comply special smoking areas are designed outside the building. The occupants are directed to these designated smoking areas with signage. This practice didn't create any additional costs.

4.1.29. Credit 1, Outdoor Air Delivery Monitoring

The intent of this credit is to monitor and ensure that the outdoor air delivery works as designed during the building life. The credit requires installation of permanent monitoring systems which generate an alarm when airflow values or carbon dioxide (CO2) levels vary by 10% or more from the design values. The alarm should trigger a visual or an audible alert to the building occupants or building management via an automated system (USGBC, 2009).

The project has placed direct airflow measurement devices on each air handling unit and connected to the central building automation system in order to comply with the credit. Additionally, CO2 sensors are placed in densely occupied spaces such as gym, cafeteria and restaurant. These units resulted in a fixed cost increase for the project.

4.1.30. Credit 3, Construction Indoor Air Quality Management Plan

The intent of this credit to prevent indoor air quality problems resulting from construction activities and promote well-being of construction workers and building occupants. An indoor air quality management plan for construction phase is developed and implemented. The plan includes measures such as protection of ductwork and air handling equipment from dust, local temporary exhaust during dust creating indoor construction activities, controlling pollution of indoor spaces, protection of sensitive materials, preventing odor and other air contaminants during construction, storing of chemicals in a separate and closed area (USGBC, 2009). These practices do not require additional costs but a good management and regular monitoring. Applied measures are photographed and documented for LEED certification. Some of the photographs can be seen in Figure 4.14-Figure 4.17.

4.1.31. Credit 4.1, Low-Emitting Materials-Adhesives and Sealants

This credit aims to reduce the amount of indoor air contaminants emitted by adhesives and sealants that are odorous, irritating and/or harmful to the well-being of construction workers and occupants. All adhesives and sealants used on the interior of the building should comply with the South Coast Air Quality Management District (SCAQMD) Rule $\neq$1168 according to LEED reference guide (USGBC, 2009). This ruling limits the content of Volatile Organic Compound (VOC) value of the products. VOCs are chemicals that evaporate and enter the surrounding air in room temperature. This results in inhaling of these chemicals when exposed to them during construction or occupancy period. The limit values according to SCAQMD Rule ≠1168 are given in Table 4.11. The products which are compliant with the ruling are available in the Turkish market. The requirements are added into the contractor's specifications in the project. Thus, the additional costs created are unknown but it is assumed to be negligible.

Figure 4.14. Sealing ductwork.

Figure 4.15. Sealing ductwork.

Figure 4.16. Protection of sensitive materials.

Figure 4.17. Storage of chemicals.

4.1.32. Credit 4.2, Low-Emitting Materials-Paints and Coatings

The goal of this credit is to reduce the amount of indoor air contaminants emitted by paints and coatings that are odorous, irritating and/or harmful to the well-being of construction workers and occupants. Paints and coatings used on the interior of the building must comply with the Green Seal Standard GS-11, Green Seal Standard GC-03 and South Coast Air Quality Management District (SCAQMD) Rule 1113. These standards limit the content of Volatile Organic Compound (VOC) value of the products (USGBC, 2009). The requirements are added into the contractor's specifications in the project. Thus, the additional costs created are unknown but it is assumed to be negligible. The manufacturer specifications of the products are collected during the construction phase and documented for LEED certification.

Table 4.11. VOC limit values (USGBC, 2009).

Architectural Applications	**VOC Limit (g/L less water)**	**Specialty Applications**	**VOC Limit (g/L less water)**
Indoor carpet adhesives	50	PVC welding	510
Carpet pad adhesives	50	CPVC welding	490
Wood flooring adhesives	100	ABS welding	325
Ruber floor adhesives	60	Plastic cement welding	250
Subfloor adhesives	50	Adhesive primer for plastic	550
Ceramic tile adhesives	65	Contact ahesive	80
VCT and asphalt adhesives	50	Special purpose contact adhesive	250
Drywall and panel adhesives	50	Structural wood member adhesive	140
Cove base adhesives	50	Sheet applied rubber lining operations	850
Multipurpose construction adhesives	70	Top and trim adhesive	250
Structural glazing adhesives	100		
Substrate Specific Applications	**VOC Limit (g/L less water)**	**Sealant**	**VOC Limit (g/L less water)**
Metal to metal	30	Architectural	250
Plastic foams	50	Roadway	250
Porous material (except wood)	50	Other	420
Wood	30		
Fiberglass	80		
Sealant Primers	**VOC Limit (g/L less water)**		
Architectural, nonporous	250		
Architectural, porous	775		
Other	750		

4.1.33. Credit 4.3, Low-Emitting Materials-Flooring Systems

This credit aims to reduce the amount of indoor air contaminants emitted by flooring materials that are odorous, irritating and/or harmful to the well-being of construction workers and occupants. LEED has specified requirements for different flooring types. The project installed natural stone flooring which doesn't emit any volatile organic compounds to the surrounding air (USGBC, 2009). Natural stone was already planned in the project. Thus, no additional costs is required for the project. The manufacturer specifications of the products are collected during the construction phase and documented for LEED certification.

4.1.34. Credit 5, Indoor Chemical and Pollutant Source Control

The purpose of this credit is to reduce the entry of pollutants into the building and expose of contaminants inside the building. In order to capture dirt and particulates entering the building through pedestrian entrances, entryway mats with a length of 3 meters are installed on every entrance (USGBC, 2009). Some building zones may contain hazardous gases and chemicals such as parking garages and housekeeping rooms. These zones are sufficiently exhausted and negative pressure is created to avoid any leakage to other zones. Additionally, self-closing doors are installed. The air handling units which derive outdoor air to the building zones have filtration media with a class of F7 by CEN Standard EN 779: 2002. The mechanical drawings and photographs are documented for LEED certification. It has a negligible impact on the project budget.

4.1.35. Credit 7, Thermal Comfort-Design

This credit aims to provide a comfortable thermal environment that promotes occupant productivity and well-being. Heating, ventilating and air conditioning (HVAC) systems are designed to meet ASHRAE 55-2004 criteria which specifies thermal environmental conditions for human occupancy such as radiant temperature, humidity ratio and indoor air speed. The mechanical design team provided documentation that shows the compliance with the ASHRAE 55-2004 via the online CBE (Center for Built Environment) Thermal Comfort Tool. The tool prepares a psychrometric chart according to metabolic rate of occupants, clothing level of occupants, internal humidity, air speed and operative temperature. As a result, the conditions (red point) should be inside the comfort zone (dark hatched area) in the chart which can be seen in Figure 4.18 (USGBC, 2009). No additional actions are needed since the existing system already provides the required comfort levels.

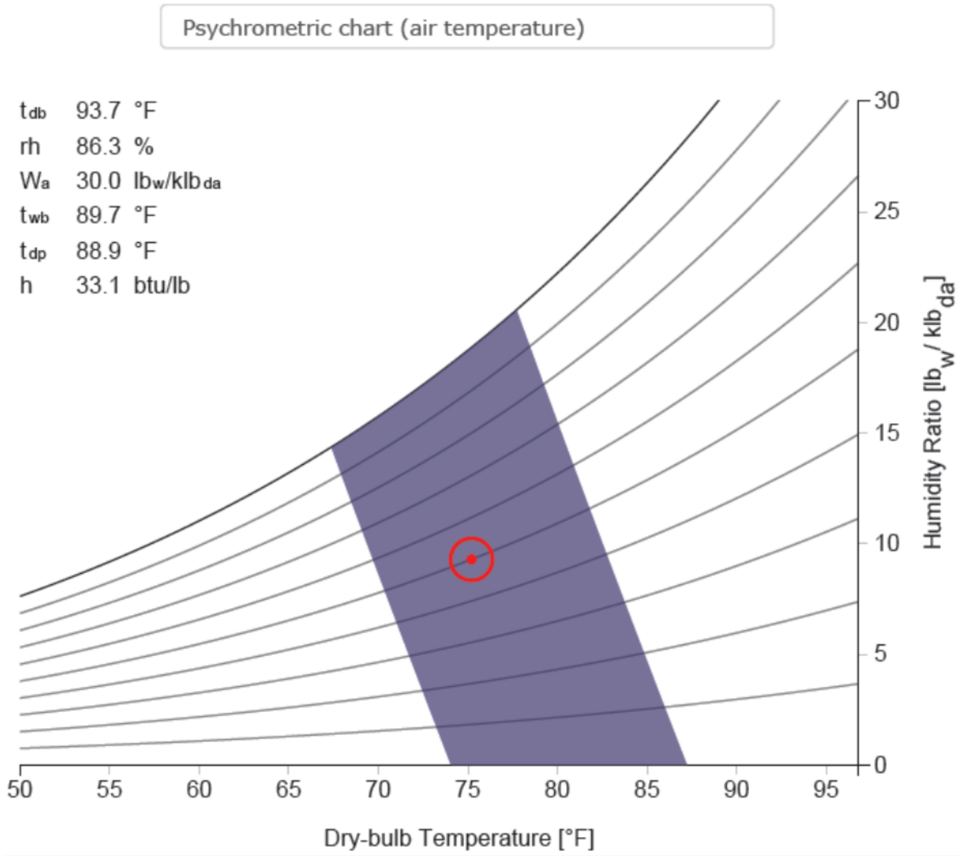

Figure 4.18. Psychrometric chart for thermal comfort (ASHRAE, 2007).

4.1.36. Credit 8.1, Daylight and Views-Daylight

The intent of this credit is to provide building occupants sufficient daylight levels to promote comfort and productivity. In order to comply with the credit, the building is virtually modeled by the computer software Designbuilder and daylight simulation is conducted. According to results of daylight simulation, 75% of all regularly occupied spaces such as offices and retail areas achieve daylight illuminance levels of a minimum of 110 lux in a clear sky condition on September 21 at 9 a.m. and 3 p.m (USGBC, 2009). The architectural design of the building was already compliant with the credit. Thus, no additional changes or costs are applicable for the credit. The simulation results are documented for LEED certification. Sample analysis results of first floor can be seen in Figure 4.19 and Figure 4.20.

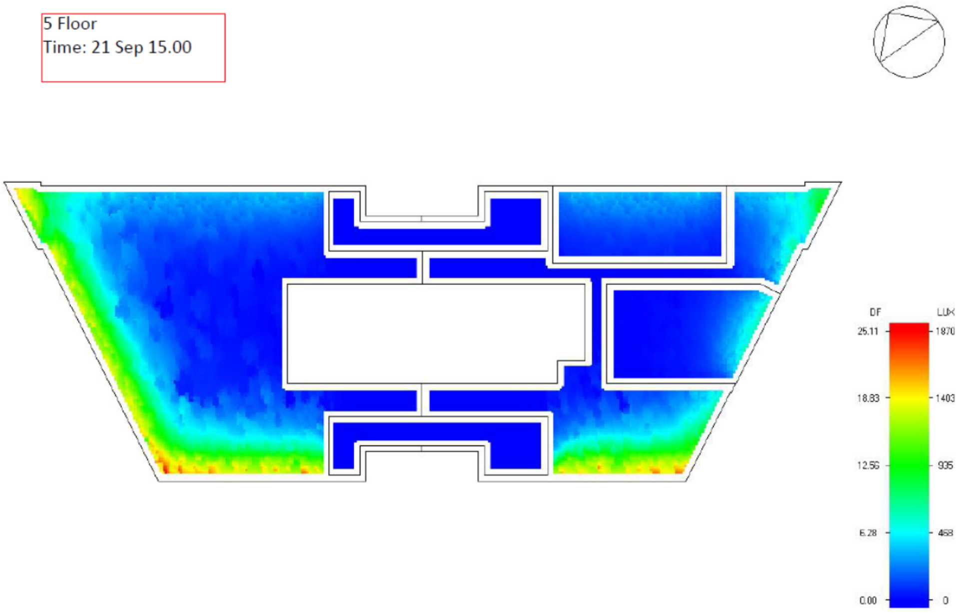

Figure 4.19. Daylight simulation results for 5. Floor, 21 Sep 15.00.

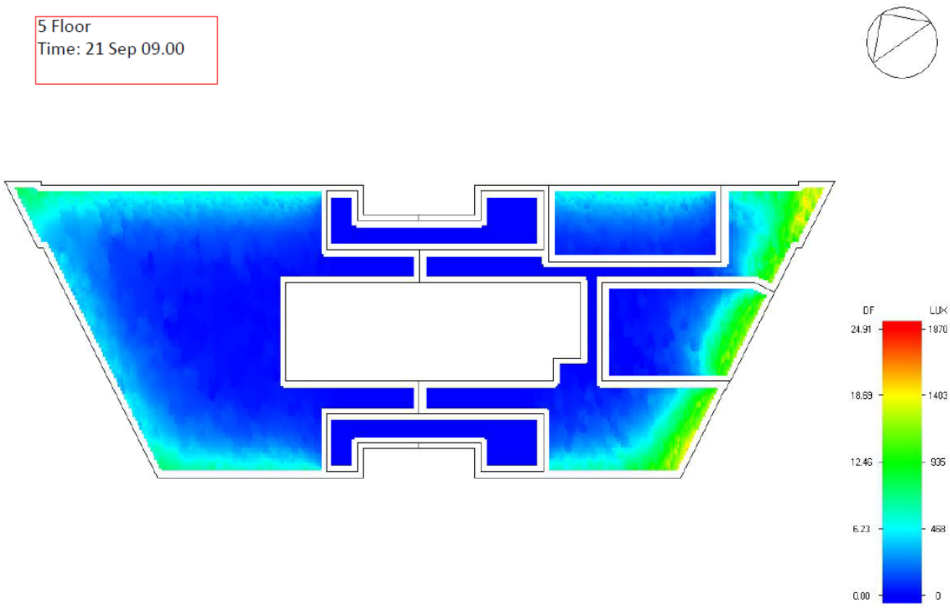

Figure 4.20. Daylight simulation results for 5. Floor, 21 Sep 09.00.

4.1.37. Credit 8.2, Daylight and Views-Views

The intent of this credit is to provide building occupants views to the outdoors. Direct line of sight to the outdoor environment via vision glazing between 0.8 meters and 2.3 meters above the finish floor for building occupants in 90% of all regularly occupied areas are achieved (USGBC, 2009). The compliance is shown via the building floor plans and sections. A sample floor plan documented to LEED can be seen in Figure 4.21. The green hatched zones have views to the outside and red hatched zones do not have view to the outside. This credit didn't require any changes in the existing architectural design.

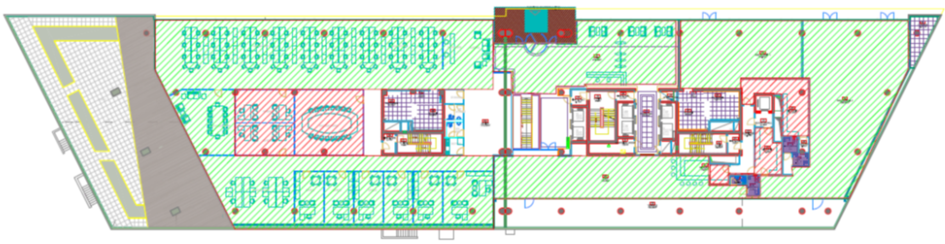

Figure 4.21. Ground floor plan showing views to outside.

4.1.38. Credit 1, Innovation in Design

The aim of this credit is to implement innovative green building strategies that are not addressed in LEED credits and achieve exceptional performance above the requirements set by LEED credits. Exceptional performance is achieved in three credits where the required LEED threshold is doubled by the project. These are Sustainable Sites Credit 2 Development Density, Sustainable Sites Credit 4.1 Alternative Transportation and Materials and Resources Credit 5 Regional Materials. These performance credits are achieved without an effort (USGBC, 2009).

Innovative performance is achieved in two different ways which are not addressed in LEED. First, the electronic waste is also collected separately besides the regular waste and delivered to the recycling facilities. All office users are encouraged to bring their electronic waste such as batteries, cartridges, monitors, phones etc. to the designated areas. Second, the building users are informed about the features of the green building and LEED certification. Users are encouraged to cooperate with the green strategies to increase water and energy savings. These credits are achieved with little effort but they didn't create significant costs.

4.1.39. Credit 2, LEED Accredited Professional

In order to achieve this credit at least one principal participant of the project team shall be a LEED Accredited Professional (USGBC, 2009). The project worked with a LEED consultancy company which has an assigned LEED AP for the project. LEED AP is included in the project from the early design to completion. LEED consultancy fees are included in the project as a fixed cost.

4.1.40. Credit 1, Regional Priority

This credit aims projects to provide an incentive for the achievement of credits that address geographically - specific environmental priorities. LEED specified some credits to be regionally more important than others and these credits give additional points if achieved. For Turkey, credits Energy and Atmosphere Credit 1 Energy Performance, Energy and Atmosphere Credit 3 Enhanced Commissioning, Water Efficiency Credit 1 Water Efficient Landscaping, Water Efficiency Credit 3 Water Use Reduction are selected for regional priority. This project achieved these credits and also regional priority credit by itself (USGBC, 2009).

4.1.41. Impact on Project Budget

In the previous chapter the green building implementation of each credit is explained and it is stated if they create additional costs or not. In this chapter, the additional costs are explained. The associated costs for each credit are investigated during the research with interviews and examinations of documents. In this study, the costs are categorized in two ways. Firstly, the costs are categorized as hard and soft costs. Hard costs are resulted from purchases of additional or more expensive materials and equipment, physical implementation of green building strategies and associated labor costs. Soft costs include LEED consultancy fees, energy modeling fees, LEED certification fees and costs related to additional paperwork. Secondly, it is found out that the costs can be classified in four categories: 1) Low size-sensitive costs 2) High size-sensitive costs 3) Costs depending the concept design 4) Negligible cost. Low size-sensitive costs are costs that have a minimum value and do not change significantly with the project size. These can also be considered as fixed costs. High size sensitive costs mainly depend on the project size and they can be considered as fixed costs per area. These costs can vary from zero to high values. Costs depending concept design are mostly depended on the project decisions and conditions. Some projects can comply with credits without any cost or any effort where some projects may result in high cost increase. Lastly, no cost credits are credits that can be achieved in almost all projects without cost increase independent from design. Credits that created additional costs are explained below:

4.1.42. Sustainable Sites Prerequisite, Construction Activity Pollution Prevention

The project implemented a truck washing area, site fencing and sediment traps where necessary. These costs are depended on the project size and included in contractor's requirements. Truck washing area and its maintenance is estimated to cost $15,000 during the construction period. Site fencing is implemented in every project of the company due to local regulations and thus it is not an additional cost for green building practice. Cost of sediment trap excavations are concluded to be negligible. This item is categorized as high size-sensitive hard cost.

4.1.43. Sustainable Sites Credit 4.2, Alternative

Transportation-Bicycle Storage and Changing Rooms In order to comply with the credit 120 bicycle racks, 15 showers and changing rooms are added into the project. Estimate cost for the bicycle racks are $6000 ($50 x 120). Estimated cost for shower and changing rooms are $15000 ($1000 x 15). Thus, they aren't evaluated as a cost for LEED. This item is categorized as high size-sensitive hard cost.

4.1.44. Sustainable Sites Credit 4.3, Alternative

Transportation-Low-Emitting and Fuel-Efficient Vehicles Preferred parking spots for low-emitting vehicles are shown with signage on the parking spots. Cost of the signage are \$225. (45 signs x \$5). This item is categorized as high size-sensitive hard cost.

4.1.45. Sustainable Sites Credit 4.4, Alternative Transportation - Parking Capacity

Preferred parking spots for carpool are shown with signage on the parking spots. Cost of the signage are \$225. (45 signs x \$5). This item is categorized as high size-sensitive hard cost.

4.1.46. Sustainable Sites Credit 5.1 and 5.2, Site Development

The amount of vegetated green area in the concept design wasn't sufficient for compliance with the credit. Thus, the project increased the green area both on the ground and on the roofs. A total of 1500 m^2 of green area on the ground and 1100 m^2 of green roof is added to the project for LEED criteria. The cost for the green area is estimated to be \$15/m^2 and green roof \$30/m^2. Total additional costs related for this credit is calculated as \$55,500 (\$15/m^2 x 1500 m^2 + \$30/m^2 x 1100 m^2). It should be noted that the increase of the green area also ensured the compliance with other sustainable sites credits: Credit 5.2 Maximize Open Space, Credit 6 Stormwater Design. This item is categorized as concept design depending hard cost.

4.1.47. Credit 6.1 and Credit 6.2, Stormwater Design

The stormwater surface run off is decreased by increasing the green area of the project. This resulted a cost increase as mentioned in the above credit.

4.1.48. Energy and Atmosphere Prerequisite 1 and Credit 3, Commissioning of Building Energy Systems

Commissioning of energy related systems is conducted by a third party company. The services the commissioning company provided includes; review of the project compliance with owner's project requirements and the basis of design in terms of commissioning; training of the team and operational personnel in the equipment and building management systems, witness and complete these training as necessary; control and review of contractor submittals; implementing performance tests; preparation of a manual for operation personnel; conduction of a seasonal commissioning within nine months; preparation of the final commissioning report. It is estimated that 3 technical persons worked for 20 days with a daily cost of $400 each. Total fee of the company is 24,000 USD. This item is categorized as low size-sensitive soft cost.

4.1.49. Energy and Atmosphere Prerequisite 2 and Credit 1, Energy Performance

The costs related to the energy performance is not easy to evaluate since there are many factors affecting the performance of a building such as orientation, architecture, envelope properties, mechanical and lighting systems. Some buildings may need huge changes and a lot of effort to achieve this credit and some buildings may achieve the credit without effort. It is mostly related on the concept design.

In this project, it is stated that there aren't any changes made in the design for the LEED purpose. The developer company aimed to have an energy efficient building before the LEED decision and energy performance credit didn't create any additional costs. The building does not include any additional systems for the purpose. Improvements to increase the energy efficiency was present. The project already complied with the energy efficiency measures such as improved insulation, efficient HVAC equipment, LED lighting. Energy simulation is conducted to calculate the energy performance and LEED points of the building. A consultancy company specialized in energy simulation is hired for the energy simulation work of the project. The fee of the company is

$20,000. This item includes both concept design depending hard cost (improvements) and soft cost (energy modeling).

4.1.50. Materials and Resources Prerequisite 1, Storage and Collection of Recyclables

For the purpose of this credit four recycle bins are provided on every floor. The cost of the bins is $800 (80 bins x $10). This item is categorized as high size-sensitive hard cost.

4.1.51. Materials and Resources Credit 6, Certified Wood

Forest Stewardship Council (FSC) certified wood is preferred during wood purchasing. The wood implemented in the building contain flooring, covering and doors. The cost premium of FSC certified wood is investigated with the wood manufacturer company. It is concluded that FSC certified wood is approximately $\$2/m^2$ more expensive than not certified wood with same properties. The project had approximately 1,000 m^2 of wood installation. It resulted a cost increase of approximately $2,000. This item is categorized as high size-sensitive hard cost.

4.1.52. Indoor Environmental Quality Credit 1, Outdoor Air Delivery Monitoring

In order to comply with the credit outdoor air flow measurement devices are added on every air handling unit in the building. The devices are connected with the building automation system which was already included in the project. Additionally, five CO2 sensors are installed in densely occupied spaces such as gym and cafeteria. Cost of the air flow measurement devices is $1500 (5 units x $300) and CO2 sensors is $1000 (5 units x $200). This item is categorized as high size-sensitive hard cost.

4.1.53. Indoor Environmental Quality Credit 5, Indoor Chemical and Pollutant Source Control

Some of the credit criteria were already included in the project as a common practice such as F7 filters and exhaust for cleaning room and garages. Entryway mats with a length of 3 meter are included on every entrance. The cost of the mats is $500 (10 mats x $50). This item is categorized as high size-sensitive hard cost.

4.1.54. LEED Consultancy Fees

The project hired a LEED consultancy company for the whole certification process. The company was available from the beginning of the design until the occupancy and managed the LEED certification. The services the LEED consultancy company provided includes; preparation of LEED documentation and sustainability charrette, establishing project goals and assigning roles, technical consultancy for project teams about sustainability practices and energy efficiency, supervision of construction activities, documentation and achievement of certification, support for green marketing. The fee of the company is $80,000. This item is categorized as low size-sensitive soft cost.

4.1.55. LEED Certification Fees

Green Building Certification Institute (GBCI) is the only authorized institution by U.S. Green Building Council that provides LEED certification in the world. The institute reviews documentation provided by LEED consultants via an online system and awards the certification accordingly. LEED certification fees which include registration fee, design review fee and construction review fee are paid to the GBCI. The fees are calculated according to building floor area. A discount is applicable for USGBC premium members. The fees can be seen in Table 4.12. The sum of fees this project is $30,000. This item is categorized as high size-sensitive soft cost.

Overall, a green building cost increase of $256,250 which is 0.42% of total budget and $3.4/m^2 is estimated. All credits and related costs are summarized in Table 4.2.1.

On the table, costliest items are development of green area, bicycle racks and showers, energy performance improvement, commissioning process, LEED certification fees and consultancy services.

4.2. Case 2: Turkish Contractors Association Headquarters

4.2.1. General Information

Turkish Contractors Association (TCA) is a non-governmental, non-profit, independent professional organization established in Ankara in 1952. Turkish Contractors Association's new headquarters building is completed in 2014 and it is aimed to set an example of a green building for the construction sector. It achieved "International Project of the Year" award at "Building Awards 2014" in United Kingdom. The building consists of five above grade and one below grade floor and total area of the building is 5,000 m^2. The project is mainly an office but it also includes a conference center, exhibition area, cafeteria and parking garage. The building is located in an urban area in Çankaya, Ankara. The site of the project is relatively small with an area of 1,250 m^2. The site contains a guest parking area, plaza area and green area. The project budget is approximately 7 million U.S. dollars according to LEED submission documents.

Table 4.12. LEED Certification Fees.

LEED Certification Fees for New Buildings	**Non-members**	**Premium members**
Registration Fee	\$1.200	\$900
Design Review Fees		
Project floor area: Less than 4500 m^2	\$2.250	\$2.000
Project floor area: 4500 m^2 to 45000 m^2	\$0.495/m^2	\$0.44/m^2
Project floor area: More than 45000 m^2	\$22.500	\$20.000
Construction Review Fees		
Project floor area: Less than 4500 m^2	\$750	\$500
Project floor area: 4500 m^2 to 45000 m^2	\$0.165/m^2	\$0.11/m^2
Project floor area: More than 45000 m^2	\$7.500	\$5.000

Table 4.13. LEED Costs of Case 1.

Credit Number/Name		Cost Type 1	Cost Type 2	Implemented Cost Items	Costs (USD)
	Sustainable Sites				
Prereq 1	Construction Activity Pollution Prevention	Hard Cost	High Size-sensitive costs	Truck wheel washing area construction and maintenance \$15000 Site fencing (already done in every project) Sediment traps: negligible cost	15000
Credit 1	Site Selection	No cost	No cost	The site meets requirements. No costs are involved.	0
Credit 2	Development Density and Community Connectivity	No cost	No cost	The site meets requirements. No costs are involved.	0
Credit 4.1	Alternative Transportation-Public Transportation Access	No cost	No cost	The site meets requirements. No costs are involved.	0
Credit 4.2	Alternative Transportation-Bicycle Storage and Changing Rooms	Hard Cost	High Size-sensitive costs	120 bicycle racks: 50x120 = 6000 USD 15 showers: 15x1000 = 15000 USD	21000
Credit 4.3	Alternative Transportation-Low-Emitting and Fuel-Efficient Vehicles	Hard Cost	High Size-sensitive costs	Parking signs for preferred parking. 45 signs x 5 = 225 USD	225
Credit 4.4	Alternative Transportation-Parking Capacity	Hard Cost	High Size-sensitive costs	Parking signs for preferred parking. 45 signs x 5 = 225 USD	225
Credit 5.1	Site Development-Protect or Restore Habitat	Hard Cost	Costs depending concept design	1500 m^2 of vegetated area and 1100 m^2 of green roof is added in the project. \$15/m^2 apx. vegetation cost. \$30/m^2 apx. green roof cost. 1500 x 15 = 22500 USD 1100 x 30 = 33000 USD	55500
	Sustainable Sites				
Credit 5.2	Site Development-Maximize Open Space	Hard Cost	Costs depending concept design	Related costs are calculated in credit 5.1	0
Credit 6.1	Stormwater Design-Quantity Control	Hard Cost	Costs depending concept design	Related costs are calculated in credit 5.1	0
Credit 7.1	Heat Island Effect-Non-roof	Hard Cost	Costs depending concept design	Underground parking meets requirements	0

Table 4.13. LEED Costs of Case 1 (cont.).

Credit Number/Name		Cost Type 1	Cost Type 2	Implemented Cost Items	Costs (USD)
	Water Efficiency				
Credit 7.2	Heat Island Effect-Roof	Hard Cost	Costs depending concept design	Cost of green roof is calculated in credit 5.1 White colored roofing does not have significant cost difference.	0
Credit 9	Tenant Design and Construction Guidelines	No Cost	No Cost	No cost	0
Prereq 1	Water Use Reduction-20% Reduction	Hard Cost	Costs depending concept design	The water fixtures are selected accordingly. No significant cost difference	0
Credit 1	Water Efficient Landscaping	Hard Cost	Costs depending concept design	Low water consuming plants are selected: No significant cost	0
Credit 2	Innovative Wastewater Technologies	Hard Cost	Costs depending concept design	The water fixtures are selected accordingly. No significant cost difference.	0
Credit 3	Water Use Reduction	Hard Cost	Costs depending concept design	The water fixtures are selected accordingly. No significant cost difference.	0

Table 4.13. LEED Costs of Case 1 (cont.).

Credit Number/Name		**Cost Type 1**	**Cost Type 2**	**Implemented Cost Items**	**Costs (USD)**
	Energy and Atmosphere				
Prereq 1	Fundamental Commissioning of Building Energy Systems	Soft Cost	Low size-sensitive Costs	Commissioning is conducted by a third party company. Apx. Fee of the company: 24,000 USD (3 technical person for 20 days 400$ each)	24000
Prereq 2	Minimum Energy Performance	Soft Cost	Costs depending concept design	A consultancy company for energy simulation is hired for the work: Apx. 20,000 $ Improvements to increase the energy efficiency is present. The project already complies with the energy efficiency measures such as improved insulation, efficient HVAC equipment, LED lighting.	20000
Prereq 3	Fundamental Refrigerant Management	No Cost	No cost	Project complies the credit with negligible effort.	0
Credit 1	Optimize Energy Performance	Soft / Hard Cost	Costs depending concept design	Cost is given in EAp2	0
Credit 3	Enhanced Commissioning	Hard Cost	Low size-sensitive costs	Cost is given in EAp1	0

Table 4.13. LEED Costs of Case 1 (cont.).

Credit Number/Name		**Cost Type 1**	**Cost Type 2**	**Implemented Cost Items**	**Costs (USD)**
Credit 4	Enhanced Refrigerant Management	No Cost	No cost	Project complies with negligible effort.	0
Credit 5.1	Measurement and Verification-Base Building	Hard Cost	Costs depending concept design	Project complies with negligible effort.	0
Credit 5.2	Measurement and Verification-Tenant Submetering	Hard Cost	Costs depending concept design	Project complies with negligible effort.	0
	Materials and Resources				
Prereq 1	Storage and Collection of Recyclables	Hard Cost	High size-sensitive costs	Recyle bins are provided on every floor. 20 x 4 = 80 bins 10 x 80 = 800 USD	800
Credit 2	Construction Waste Management	No Cost	No cost	Recycable materials are seperated on the site and delivered to the recycling facilities by municipality. Negligible cost.	0
Credit 4	Recycled Content	No Cost	No cost	Project complies with negligible effort.	0
Credit 5	Regional Materials	No Cost	No cost	Project complies with negligible effort.	0

Table 4.13. LEED Costs of Case 1 (cont.).

Credit Number/Name		Cost Type 1	Cost Type 2	Implemented Cost Items	Costs (USD)
Credit 6	Certified Wood	Hard Cost	High size-sensitive costs	FSC certified wood is preferred during wood purchasing. 1000 m^2 of wood, cost increase apx. 2 $\$/m^2$	2000
	Indoor Environmental Quality				
Prereq 1	Minimum Indoor Air Quality Performance	No Cost	No cost	Project complies with negligible effort.	0
Prereq 2	Environmental Tobacco Smoke (ETS) Control	No Cost	No cost	No costs	0
Credit 1	Outdoor Air Delivery Monitoring	Hard Cost	High size-sensitive costs	Addition of outdoor air flow measurement devicefor 5 air handling units. 5 x 300 = 1500 USD Placement of CO2 sensors in 5 rooms: 5 x 200 = 1000 USD	2500
Credit 2	Increased Ventilation	No Cost	No cost	Project complies with negligible effort.	0
Credit 3	Construction Indoor Air Quality Management Plan-During Construction	No Cost	No cost	The requirements are added into the contractor's specifications. Related costs are unknown but it is assumed negligible	0
Credit 4.1	Low-Emitting Materials-Adhesives and Sealants	No Cost	No cost	The requirements are added into the contractor's specifications. Related costs are unknown but it is assumed negligible	0

Table 4.13. LEED Costs of Case 1 (cont.).

Credit Number/Name		Cost Type 1	Cost Type 2	Implemented Cost Items	Costs (USD)
Credit 4.2	Low-Emitting Materials-Paints and Coatings	No Cost	No cost	The requirements are added into the contractor's specifications. Related costs are unknown but it is assumed negligible	0
Credit 4.3	Low-Emitting Materials-Flooring Systems	Hard Cost	Costs depending concept design	Natural stone flooring complies with the credit.	0
Credit 5	Indoor Chemical and Pollutant Source Control	Hard Cost	High size-Sensitive costs	F7 filters and exhaust for cleaning room and garages are already present in the building. 3-meter-long entryway mats are put on every entrance. 10 x 50 = 5000 USD	5000
Credit 7	Thermal Comfort-Design	No Cost	No cost	Project complies with negligible effort.	0
Credit 8.1	Daylight and Views-Daylight	Hard Cost	Costs depending concept design	Project complies with negligible effort.	0
Credit 8.2	Daylight and Views-Views	Hard Cost	Costs depending concept design	Project complies with negligible effort.	0

Table 4.13. LEED Costs of Case 1 (cont.).

Credit Number/Name		Cost Type 1	Cost Type 2	Implemented Cost Items	Costs (USD)
	Innovation and Design				
Credit 1	Innovation in Design: Specific Title	No Cost	No cost	Project complies with negligible effort.	0
Credit 2	LEED Accredited Professional	Soft Cost	Low size-sensitive costs	Included in LEED consultancy fees	0
	Regional Priority				
Credit 1	Regional Priority: Specific Credit	No Cost	No cost	Project complies with negligible effort.	0
LEED Certification Fees		Soft Cost	High size-Sensitive costs	Calculated by floor area	30000
Consultancy Fees		Soft Cost	Low size-sensitive costs	LEED consultancy service costs	80000
	Total cost (USD)				**256250**

Table 4.14. Project Team of Case 2.

Project Team	**Company**
Project Management	IMS
Architectural Design	Avci Architects
Mechanical Design	Okutan Engineering
Electrical Design	Yurdakul Engineering
Structural Design	Ural Engineering
General Contractor	MESA Construction
Sustainability Consultant	Atelier10
LEED Consultant	Turkeco Consultancy
Acoustical Consultant	Mezzo
Commissioning Agent	Çakmanus Engineering

4.2.2. Green Building Implementation

In order to reflect TCA's commitment to promote "sustainable construction", the project didn't limit itself with the LEED criteria and included many other innovative strategies of energy efficiency, natural ventilation and air-conditioning applications. In terms of passive heating and cooling techniques, the building embodies some systems to be used for the first time in Turkey. Energy performance has been optimized through installation of a concrete labyrinth as a third basement, getting use of the most significant feature of typical climatic conditions in Ankara; day and night temperature differences.

The project achieved 81 points out of 110 points of LEED. The list of achieved LEED criteria is given in Table 4.2.2. Some criteria of LEED are prerequisites and they are mandatory for every level of certification. Criteria that the project implemented are explained in detail in this chapter under each category. Requirements are shortly described according to USGBC (2009) LEED Reference Guide and implementation to fulfil the requirement is explained.

Figure 4.22. Outside view of the project.

Table 4.15. Scorecard of Case 2.

Sustainable Sites		**Possible Points**	**Achieved Points**
Prereq 1	Construction Activity Pollution Prevention	Prerequisite	
Credit 1	Site Selection	1	1
Credit 2	Development Density and Community Connectivity	5	5
Credit 3	Brownfield Redevelopment	1	0
Credit 4.1	Alternative Transportation-Public Transportation Access	6	6
Credit 4.2	Alternative Transportation-Bicycle Storage and Changing Rooms	1	1
Credit 4.3	Alternative Transportation-Low-Emitting and Fuel-Efficient Vehicles	3	3
Credit 4.4	Alternative Transportation -Parking Capacity	2	2
Credit 5.1	Site Development-Protect or Restore Habitat	1	0

Table 4.15. Scorecard of Case 2 (cont.).

Sustainable Sites		**Possible Points**	**Achieved Points**
Credit 5.2	Site Development-Maximize Open Space	1	1
Credit 6.1	Stormwater Design-Quantity Control	1	1
Credit 6.2	Stormwater Design-Quality Control	1	0
Credit 7.1	Heat Island Effect-Non-roof	1	1
Credit 7.2	Heat Island Effect-Roof	1	1
Credit 8	Light Pollution Reduction	1	0
Water Efficiency			
Prereq 1	Water Use Reduction -20% Reduction	Prerequisite	
Credit 1	Water Efficient Landscaping	4	4
Credit 2	Innovative Wastewater Technologies	2	2
Credit 3	Water Use Reduction	4	4
Energy and Atmosphere			
Prereq 1	Fundamental Commissioning of Building Energy Systems	Prerequisite	
Prereq 2	Minimum Energy Performance	Prerequisite	
Prereq 3	Fundamental Refrigerant Management	Prerequisite	
Credit 1	Optimize Energy Performance	19	8
Credit 2	On-Site Renewable Energy	7	4
Credit 3	Enhanced Commissioning	2	2
Credit 4	Enhanced Refrigerant Management	2	2
Credit 5	Measurement and Verification	3	3

Table 4.15. Scorecard of Case 2 (cont.).

Sustainable Sites		**Possible Points**	**Achieved Points**
Credit 6	Green Power	2	0
Materials and Resources			
Prereq 1	Storage and Collection of Recyclables	Prerequisite	
Credit 1	Building Reuse-Maintain Existing Walls, Floors, and Roof	4	0
Credit 2	Construction Waste Management	2	2
Credit 3	Materials Reuse	1	0
Credit 4	Recycled Content	2	2
Credit 5	Regional Materials	2	2
Credit 6	Rapidly Renewable Materials	1	1
Credit 7	Certified Wood	1	1
Indoor Environmental Quality			
Prereq 1	Minimum Indoor Air Quality Performance	Prerequisite	
Prereq 2	Environmental Tobacco Smoke (ETS) Control	Prerequisite	
Credit 1	Outdoor Air Delivery Monitoring	1	1
Credit 2	Increased Ventilation	1	1
Credit 3.1	Construction Indoor Air Quality Management Plan-During Construction	1	1
Credit 3.2	Construction Indoor Air Quality Management Plan-Before Occupancy	1	1
Credit 4.1	Low-Emitting Materials-Adhesives and Sealants	1	1
Credit 4.2	Low-Emitting Materials-Paints and Coatings	1	1

Table 4.15. Scorecard of Case 2 (cont.).

Sustainable Sites		**Possible Points**	**Achieved Points**
Credit 4.3	Low-Emitting Materials-Flooring Systems	1	1
Credit 4.4	Low-Emitting Materials-Composite Wood and Agrifiber Products	1	0
Credit 5	Indoor Chemical and Pollutant Source Control	1	1
Credit 6.1	Controllability of Systems-Lighting Comfort	1	1
Credit 6.2	Controllability of Systems-Thermal Comfort	1	1
Credit 7.1	Thermal Comfort-Design	1	1
Credit 7.2	Thermal Comfort-Verification	1	1
Credit 8.1	Daylight and Views-Daylight	1	0
Credit 8.2	Daylight and Views-Views	1	1
Innovation and Design			
Credit 1	Innovation in Design: Specific Title	5	4
Credit 2	LEED Accredited Professional	1	1
Regional Priority			
Credit 1	Regional Priority: Specific Credit	4	4
Total Points		**110**	**81**

Sustainable sites category deals with the issues related to site location, its relation with surroundings and how the open space is designed.

4.2.3. Prerequisite 1, Construction Activity Pollution Prevention

The intent of this prerequisite is to reduce pollution from construction activities by controlling soil erosion, waterway sedimentation and airborne dust generation as explained in the previous section (USGBC, 2009).

The site is closed with perimeter fencing. Perimeter fencing is implemented without any holes under or between to avoid any soil or dust escaping from the site. Geotextile is buried under the fencing to avoid soil flow after heavy rain. Photographs of the fencing can be seen in Figure 4.23 and Figure 4.24.

Figure 4.23. Site Fencing of Case 2.

Figure 4.24. Site fencing of Case 2.

The excavation soil is stored protected from wind and rain to prevent soil sedimentation in the sewers. The photograph of the soil storage is given in Figure 4.25.

Figure 4.25. Protection of Sand Stockpile in Case 2.

In order to prevent dust and particulate matter pollute the surrounding the wheels of leaving vehicles are cleaned and topside of the trucks are covered. Photographs are documented for LEED certification. Sample photographs can be seen in Figure 4.26 and Figure 4.27. the implementations are included in the contractor's requirements and additional costs are present.

Figure 4.26. Wheel washing of Case 2.

Figure 4.27. Truck covering of Case 2.

4.2.4. Credit 1, Site Selection

The intent of this credit is to avoid the development of inappropriate sites as explained in the previous section (USGBC, 2009). The site of the project was used as warehouse before and it doesn't qualify any of these options by itself. The credit is taken without any effort.

4.2.5. Credit 2, Development Density and Community Connectivity

The intent of this credit is to channel development to urban areas with existing infrastructure, protect green fields and preserve habitat and natural resources (USGBC, 2009). A map of surroundings is prepared in order to show the building density in the community. Each number on the map presents a building block. The approximate floor and site area of each building block is documented. The map can be seen in Figure 4.28.

Figure 4.28. Development density map of Case 2.

4.2.6. Credit 4.1, Alternative Transportation-Public Transportation Access

The project must be located within 800 meters of a subway or railway station or 400 meters of a bus station. The project complied with this credit since bus stations are located in close distance. A map showing the bus stops near the site is prepared as shown in Figure 4.29.

Figure 4.29. Transportation map of Case 2.

4.2.7. Credit 4.2, Alternative Transportation-Bicycle Storage and Changing Rooms

Bicycle racks for 5% or more of all building users (measured at peak periods), and shower and changing facilities in the building for 0.5% of employee is designed to achieve this credit (USGBC, 2009). The bicycle racks are put in the garage next to the entrances. Shower and changing facility is open to all employee and located in the basement floors. It is estimated that 200 people will use the building in a peak moment. Thus, 14 secure bicycle racks and 2 showers are provided. Implementation of these facilities resulted in additional costs per unit area.

4.2.8. Credit 4.3, Alternative Transportation - Low - Emitting and Fuel - Efficient Vehicles

5% of the carpark which is closest to the building entrances are reserved for green cars. Green cars are defined as low-emitting and fuel-efficient cars which include electric cars and hybrid cars (USGBC, 2009). The capacity of total carpark in the project is 25. 2 spaces closest to the entrances are reserved for green cars. The credit is achieved with a small cost of signage. The reserved spaces are documented for LEED by showing them on the plans as it can be seen in Figure 4.30.

4.2.9. Credit 4.4, Alternative Transportation-Parking Capacity

The number of provided car park cannot exceed the minimum number given in the local regulation (USGBC, 2009). Local car parking regulation requires one car park for 50 m^2 of office space. The project office area is 2,500 m^2 and 50 (2500/50) spaces are allowed. The project has only 25 parking space. Thus, the credit is achieved without additional costs but it was depended on the concept architectural project.

4.2.10. Credit 5.2, Site Development - Maximize Open Space

20% of total site area (including building footprint) should be landscaped or open to pedestrian access including green roof (USGBC, 2009). The project site has 480 m^2 of open space containing green and pedestrian area which is 34% of total site. The credit is achieved without additional costs but it was depended on the concept architectural project which includes a large portion of green and pedestrian area.

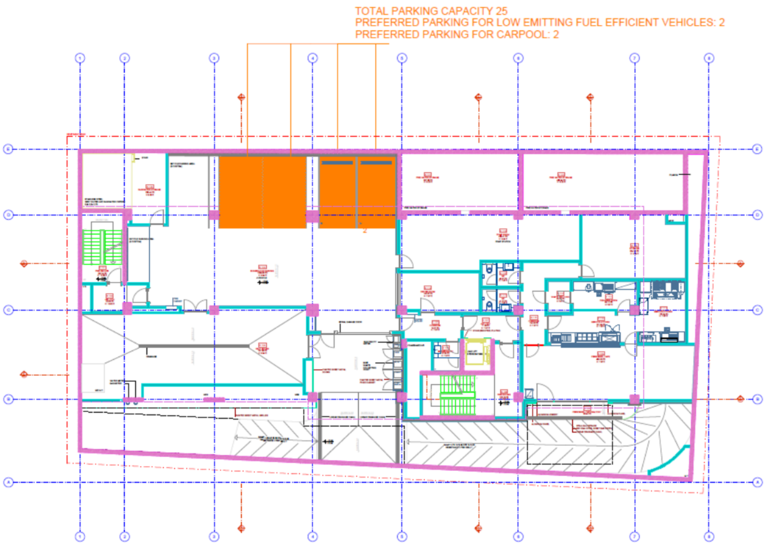

Figure 4.30. Reserved parking signage of Case 2.

4.2.11. Credit 6.1, Stormwater Design-Quantity

A stormwater management plan is implemented that results in a 25% decrease in the volume of stormwater surface runoff from the two-year 24-hour design storm compared to previous condition of the site. The following steps are taken to calculate and reduce the surface runoff (USGBC, 2009). The project site is located in Ankara, Turkey. Ankara is in the middle of Anatolian Region, which has mostly continental climate with a low rainfall intensity. Dokuz Eylul University has published a study on the rainfall analysis of Ankara. The 2yr 24hr value of Ankara has been obtained from this study. The 2yr 24hr stormwater value of Ankara is 1.24 mm/hr which equalent to 1.17 inches/24hr. The stormwater calculations are made according to Rational Method of North Carolina Department of Environment and Natural Resources (NCDENR)

Stormwater BMP Manual Chapter 3. Vegetated areas are maximized as much as possible for a better stormwater control. Rainwater is collected from the roof and terraces to use for irrigation, closets and urinals. A small portion of the roof is designed as green roof. According to calculations 2yr 24hr stormwater quantity will be reduced from 35 m^2 to 25 m^2 after construction. This results in a reduction of 30%. The implementation of rainwater collection resulted in additional costs.

4.2.12. Credit 7.1, Heat Island Effect - Non - roof

In order to avoid heat island effect, LEED requires that 50% of car park should be underground or shaded (USGBC, 2009). 80% of carpark is located under the buildings in the project. Thus, the credit is achieved without additional costs but it was depended on the concept architectural project.

4.2.13. Credit 7.2, Heat Island Effect - Roof

One of the reasons of the heat island effect is the materials used on the building roofs. Materials with low SRI (Solar Reflectance Index) absorb much of the heat and this is resulting heating of the building and surroundings (USGBC, 2009). In order to avoid this situation, materials which have SRI values higher than 78 or green roofs should be installed on the roof. In this projects, green roof and white colored roofing membrane cover materials are implemented on the roof. White colored roofing membrane has an SRI of 102. The green roof has a relatively small area of 60 m^2. It is installed as a showCase for the building. This implementation does have costs per unit area of green roof and membrane.

Figure 4.31. Green roof implementation of Case 2.

4.2.13.1. Water Efficiency. This category evaluates the buildings domestic and landscaping water consumption.

4.2.14. Prerequisite 1, Credit 2 and Credit 3, Water Use Reduction

In order to achieve water use reduction and even achieve more savings than the credit requires, the project installed a grey water treatment system (USGBC, 2009). Grey water coming from lavatories and rain water is treated and re-used in the water closets and urinals. This resulted 60% reduction of water consumption which means 200 tons of water is saved annually from building domestic water use.

The project uses grey and rainwater collection systems to reduce the water consumption. Grey water collected from showers and lavatory will directed to the closets and urinals. The grey water tank is 750 liters and filtration capacity is 1 m3/day. Daily grey water need is calculated as 225 liters according to LEED standard calculations. The water tank and filtration capacity is sufficient to provide all the grey water needed for closet and urinals. Rest of the grey water which is 150 liters/day is directed to the irrigation.

The Table 4.17 shows the consumption values and selected equipment model. The project complies with the prerequisite, credit 2 and credit 3 by choosing these water fixtures and implementing grey water recycle. These fixtures can be found in the Turkish market and there is not a significant cost premium. Grey water treatment and related plumbing work created additional costs.

4.2.15. Credit 1, Water Efficient Landscaping

Landscape designer of the project selected low water consuming plants and grey water is re-used for the irrigation (USGBC, 2009). The green area of the project is relatively small with a total of 500 m^2 of green area including green roof.

Table 4.16. Water fixtures of Case 2.

Fixture Type	**Baseline Consumption Value**	**Installed Consumption Value**	**Unit**	**Brand**	**Model**
Water Closets	6	2.50 - 4.00	liter/flush	VITRA	733-5800
Lavotaries	2	2	liter/min	ARTEMA	A41719
Urinal	4	1	liter/flush	VITRA	Watersmart 4339
Shower Head	9.5	6	liter/min l	VITRA	Istanbul A4801592
Kitchen Sink	8.5	6	liter/min	VITRA	AQUASEE

The plants are selected according the climate of Ankara. Ankara is situated in central Anatolia, it has a continental climate, with cold, snowy winters due to its elevation and inland location, and hot, dry summers. Rainfall occurs mostly during the spring and autumn. Under Kuppen's climate classification, Ankara features a semi-arid climate. Because of Ankara's high altitude and its dry summers, nightly temperatures in the summer months are cool. Ankara's annual average precipitation is fairly low, nevertheless precipitation can be observed throughout the year. The landscape design is made by Arikan Landscape Architecture Company. The design is made to fit the LEED credits SSc5 Site Development and WEc1 Water Efficient Landscaping. Firstly, flora of Ankara is determined from several sources. Arikan Company got help from Landscape Architecture Faculty of METU (Middle East Technical University) and as a reference book “Zur Flora Von Ankara, Kurt Krause” has been used. Also adapted plants mostly came from Japan is determined. After determination of options, plants are selected according to their look and water consumption. In this climate conditions, there are only needle-leaved and coniferous trees, some scrubs types and ground cover plants which can live four seasons. Irrigation issue is specially examined by Arikan Landscape Company. Landscape design is made so that plants live mutually and don’t need additional water. There will only be green needle-leaved small trees which will stay green four seasons. Also, ground cover on the green roof and garden will not stay green four seasons to avoid excess water consumption.

Table 4.17. Plants selected in Case 2.

Local Plant Name	**Latin Name**
Mavi Ladin	Picea pungens glauca
Berberis	Berberis thunbergii nana
Ardiç	Juniperus chinensis
Adi simsir	Buxus sempervirens
Compacta nana	Thuja compacta nana
Akça agaci	Acer palmatum atropurpureum
Selvi	Cupressus sempervirens
Ground cover of green roof:	Sedum Crassulaceae (60%), Sedum Album (30%), Sedum Reflexum (10%) Laurus nobili

4.2.15.1. Energy and Atmosphere. Energy and Atmosphere category includes credits about maximizing energy efficiency, renewable energy production, energy monitoring and depletion of ozone layer.

4.2.16. Prerequisite 1 and Credit 3, Commissioning of Building Energy Systems

In this project an external commissioning company was present from early design to the occupation of the building. All process is reviewed by this company as a third eye and reports are prepared to avoid any deficiency in the future. Also, training and system manual are prepared for the building management personnel. This credit created additional cost since a third party company must be hired for the job.

4.2.17. Prerequisite 2-Credit 1, Energy Performance

This is the most important credit of the LEED certification with a total available points of 19. The intent of the credit is to establish the level of energy efficiency for the proposed building and systems to reduce environmental and economic impacts associated with excessive energy use as explained in the previous section. The energy efficiency of the building is measured by doing building energy modeling (USGBC, 2009).

The Turkish Contractors Association Headquarters is aimed to be an integration of numerous technologies and highly efficient building. The building is designed to adopt and utilize the local climate conditions and resources to optimize the environmental performance. A thermal mass storage is created via an underground labyrinth which is placed at the lowest level of the building and an active integrated thermal slab with chilled beams.

The labyrinth is an innovative practice, used for the first time in Turkey, in the summer the labyrinth utilizes the naturally available cold in the night time atmosphere where temperatures fall by 15-20 °C from day to night. Additionally, the earth below ground is at a constant average temperature around 16C in Ankara throughout the year. In summer, this heat is stored in the labyrinth during the night and used in the day when the temperatures increase. In winter, the heat of ground is used to pre-heat the outside air since labyrinth air is warmer than outside air. The system provides savings of between 35-40% in heating and cooling costs according to modeling done by the sustainability consultant. The sketch of the air labyrinth can be seen in Figure 4.33.

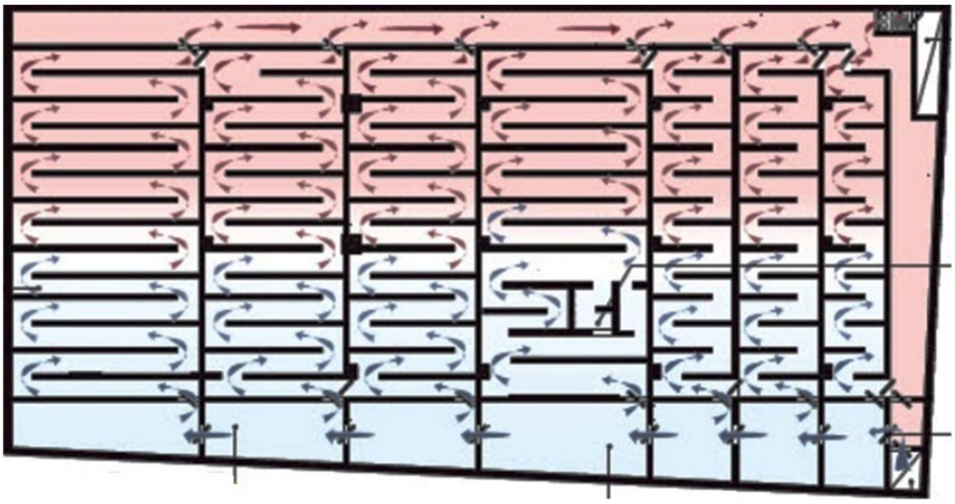

Figure 4.32. Air labyrinth.

Figure 4.33. Photograph of air labyrinth.

Besides, the labyrinth the building contains many other strategies. One of them is the atrium in the center of the building. This atrium has a glass roof which lets the heat and light of sun penetrate the building. In summer, the warm air inside the building rise through this atrium and the automated ventilation windows on the roof is opened. This provides natural ventilation and cooling. In winters, the excess heat is released is retained without opening the roof windows and the building is heated.

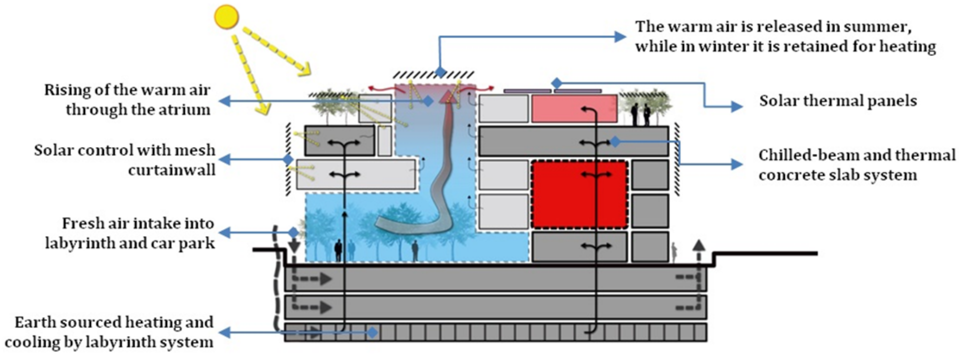

Figure 4.34. Building section with comments about strategies.

Another important energy efficiency measure in the design of the building is the active thermal floor slabs coupled with the active chilled beam systems. After the fresh air travels through the labyrinth, it enters the air handling units. Secondary ductwork distributes air to the individual floors via dedicated ventilation risers. The ductwork on each floor will then distribute through a central corridor and will interface with the active thermal mass on the office floors coupled with the active chilled beams. Small bore ductwork cast in concrete slabs provide a surface to absorb internal gains and depending on the season either warm or cool the incoming air into the internal spaces, therefore reducing energy usage at the air handling unit and minimizing the chilled beam cooling or heating requirement. The bore ductwork inside the slabs can be seen in Figure 4.36 and Figure 4.37.

Figure 4.35. Duckwork inside the slab.

Figure 4.36. Building section with comments about strategies.

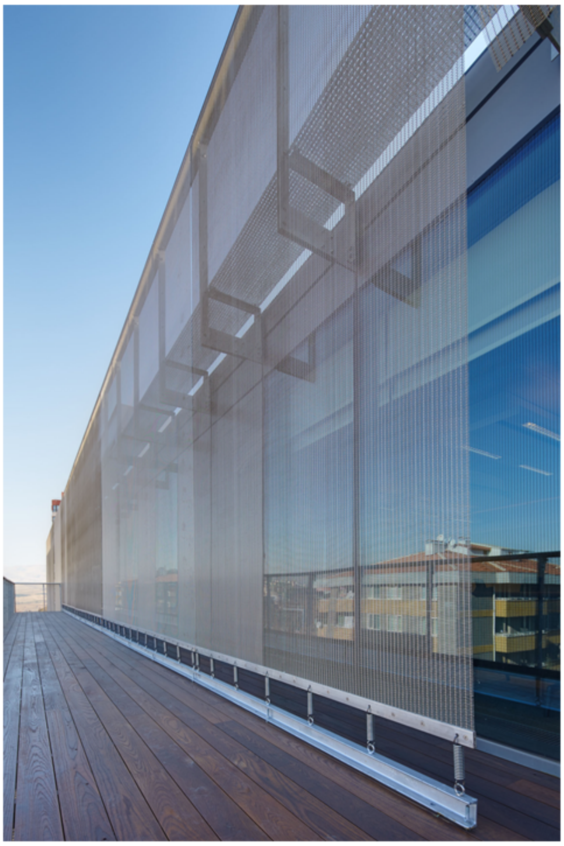

Figure 4.37. Duckwork inside the slab.

The building has a mainly transparent shell. However, modeling showed that external shading devices can contribute to the energy efficiency. After energy modelling and testing, majority of the surfaces of the building facade are shaded with a second layer of stainless steel metal mesh. The solar heat gain and therefore cooling energy needs have been minimized by means of three varying densities of mesh designed to cope with the three different solar orientations of the building. A photograph of mesh design can be seen in Figure 4.38.

Additionally, the building installed photovoltaic panels and domestic water heating solar panels on the roof to support the energy consumption of the building. 38 PV panels are installed on the roof which provide approximately 30,000 kWh of energy annually. The photograph of the panels can be seen in Figure 4.39.

Figure 4.38. External mesh shading.

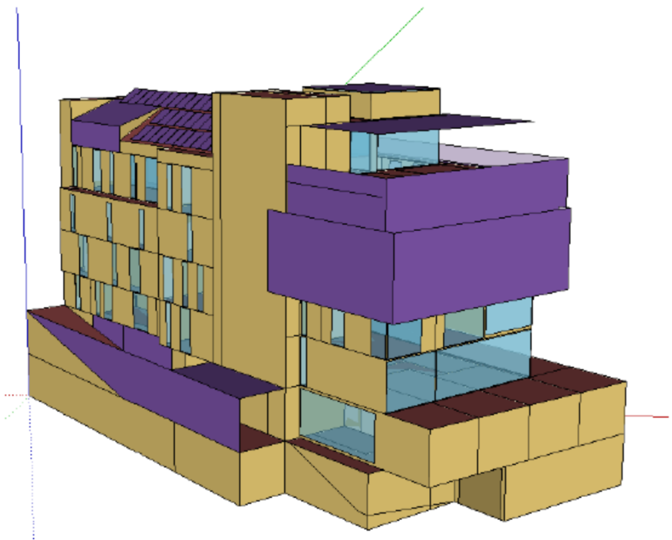

Figure 4.39. Photovoltaic panels.

Besides the innovative strategies implemented in the building, conventional efficiency measures are also taken such as better insulation rates and low lighting power densities. The building envelope thermal properties are designed to increase energy efficiency. The thermal properties of the project compared to ASHRAE 90.1-2007 baseline values can be seen in Table 4.18. Thermal conductance of a material is defined with its overall heat transfer coefficient (U-value). The lower the U-value, the less is the heat transfer through the material. This means lower U-values increase energy efficiency in most of the Cases. Window glass has a U-value and Solar Heat Gain Coefficient (SHGC). SHGC is expressed as a number between 0 and 1. The glass with lower SHGC transmits less solar energy inside the building. In sunny climates SHGC value has a significant impact on cooling loads.

Table 4.18. Comparison of Thermal Properties of Case 2

	Proposed		**Baseline (ASHRAE, 2007)**	
Building Element	U Factor (W/m^2 K)		U Factor (W/m^2 K)	
Roof	0.17		0.273	
Exterior Wall	0.272		0.365	
Window	1	0.28 SHGC	3.12	0.39 SHGC

All modeling requirements for calculating baseline building performance based on ASHRAE- 90.1 2007. The type of the building is nonresidential and more than 5 floors or > 14.000 m^2, so the System type of the baseline building is 7- VAV with reheat. The fan control is VAV, cooling type is chilled water and heating type is hot-water fossil fuel boiler. Equipment capacities are oversized 15% for cooling, 25% for heating. Supply and return fans are operated continuously whenever spaces are occupied. Minimum outdoor air ventilation rate is same with proposed building. Air economizer is included in baseline HVAC system. Economizer High-limit shutoff is 24 C0 for 3C climate zone. Supply air to room temperature difference is 11C for baseline model. Exhaust air energy recovery doesn't include in baseline model because cooling climate zone is 3C. Hot water supply/return temperatures are modeled as 82/54 C0; chilled water supply/return temperatures are modeled as 6,7/13 C.

The lighting power density of the building is reduced by selecting LED lighting as much as possible. The lighting power densities of the proposed model and baseline model according to ASHRAE 90.1-2007 can be seen in Table 4.19.

Table 4.19. Comparison of Lighting Power Densities of Case 2.

Zone Name	**Proposed Model Lighting [W/m^2]**	**Baseline Model Lighting [W/m^2]**
CARPARK	1.5	2
KITCHEN	8	13
TECHNICAL ROOM	5	16
CIRCULATION	3	6
CONFERENCE ROOM	14	14
WC	5	10
OFFICE	8.5	12
MECHNICAL ROOM	5.61	16
CAFE	12	15

The building and its strategies are modeled with the Energy Plus software. Figure 4.40 shows the model view constructed in Energy Plus modeling software.

Figure 4.40. Model View of Case 2.

Final results show that the proposed building is more than 43% more energy efficient and 27% cost efficient compared to baseline building. The energy costs are calculated according to local energy fees. Table 4.20 shows the consumption values and costs of proposed and baseline buildings. As a result, the building achieved 8 points in this credit.

Table 4.20. Energy Modeling Results of Case 2

Energy Consumption Results				
	Proposed Electricity	**Proposed Natural Gas**	**Baseline Electricity**	**Baseline Natural Gas**
Annual Consumptions (kWh)	239.069	129.779	247.429	399.193
Improvement by energy consumption	43.75%			
Energy Costs ($)	31.318	6.229	32.413	19.161
Improvement by cost	27.12%			

The innovative strategies implemented in this building affected all building design and structure. Thus, they created a high increase in the construction costs. It is seen by the project team that it is possible to achieve same LEED points with less cost increase. However, the goal of the project is to create an innovative and sustainable building beyond LEED certification.

4.2.18. Prerequisite 3 and Credit 4, Refrigerant Management

In this project, R-134A, R-410A and R407-C types of refrigerant gases are used and they are compliant with the certification criteria. There aren't any additional costs for this credit (USGBC, 2009).

4.2.19. Credit 2, On-site Renewable Energy

The project implemented two types of renewable energy systems, photovoltaic panels and solar water heaters. They are located in the building roof, both with an angle of 30 degrees looking to south. 44 Photovoltaic panels with a capacity of 250 W (LCS Solarstrom AG Model: LCS-M^{2}50-JA/SI). Total capacity is 11 kW. Gross area is 75 m^2. Total gained energy is calculated by the modeling tool and the result is 21,902 kWh energy annually. 10 Solar water heater panels are implemented with a net area of 15 m^2. The produced energy is modeled by T-SOL Pro software. Calculated energy saving is 8,142 kWh. Total renewable energy production is approximately 30,000 kWh which is 7.2% of the annual building consumption. The project achieved 4 points from this credit. The implementation of the systems resulted in a cost increase.

Table 4.21. LEED points vs. renewable energy ratio (USGBC, 2009).

Percentage Renewable Energy	**Points**
1%	1
3%	2
5%	3
7%	4
9%	5
11%	6
13%	7

4.2.20. Credit 5, Measurement and Verification

A measurement and verification plan is prepared for the project. Metering equipment to measure energy use of cooling, heating and other electrical systems are installed. These meters are connected to a central automation system which monitors and reports the consumption results regularly. The performance of these systems are compared with predicted performance and broken down by component or system as appropriate. Any deficiencies will be investigated by the building management. Evaluate energy efficiency by comparing actual performance to baseline performance. Metering equipment and automation system is already planned in concept stage in this project.

Thus, the costs are depended on the concept design.

4.2.20.1. Materials and Resources. Materials and resources category includes credits is mainly related to production construction materials and recycle opportunities.

4.2.21. Prerequisite 1, Storage and Collection of Recyclables

Easily-accessible areas for all building users are designed for the collection and storage of recycle materials. The recycle bins are for paper, glass, plastics and metals. The bins are located on the common areas next to elevators on every floor.

4.2.22. Credit 2, Construction Waste Management

A construction waste management plan is developed and implemented which identifies the materials to be diverted from disposal and whether the materials will be sorted on-site or commingled. The plan includes detailed measures to minimize the creation of construction and demolition waste on the project site and recycle and/or salvage non-hazardous construction, demolition, and land clearing debris. Construction waste management plan is prepared by LEED consultant and contractor. The waste is separated on the site during the construction and delivered to the related recycling facilities. Sample photographs of waste separation can be seen in Figure 4.41. As a result, the project diverted 86% of construction waste from landfill and delivered to recycle facilities. Waste types delivered to the recycling are steel, metals, concrete, paper and plastic packages. There are limited additional costs of waste separation.

Figure 4.41. Plastic waste area.

4.2.23. Credit 4, Recycled Content

Typically, new rebar used in reinforced concrete structure are produced from scrap iron collected from the region. It does have around 95% post-consumer content. Thus, for the reinforced concrete structures this credit is achieved without any costs. Additionally, in this project aluminum framing located on the building façade contain 22% pre-consumer content according to aluminum manufacturer. Manufacturer letters and explanations are documented for LEED certification. As a result, construction materials achieved 37% recycled content.

4.2.24. Credit 5, Regional Materials

A minimum of 20%, based on cost, of the total construction materials value should be regional (USGBC, 2009). In this project, most of the construction materials are manufactured within 800 km. concrete and stone is manufactured within 800 km. Manufacturer letters and explanatory documents are used for LEED documentation. As a result, 55% of all construction materials are regional.

4.2.25. Credit 6, Rapidly Renewable Materials

Rapidly renewable building materials and products are made from agricultural products that are typically harvested within a 10-year or shorter cycle. Materials such as bamboo, cork, linoleum, wheat are considered rapidly renewable. The intent is to use rapidly renewable building materials and products for 2.5% of the total value of all building materials and products used in the project, based on cost (USGBC, 2009). The project has chosen linoleum flooring in some zones and cork sound insulation panels to comply with the credit. There is not significant cost increase.

4.2.26. Credit 7, Certified Wood

In this project, main wood products are doors and terrace wood flooring. Wood flooring in terraces are purchased FSC certified wood (USGBC, 2009). The FSC certification proof of installed materials are requested from the companies and documented for LEED certification. As a result, 61% of all wood products used in the building is FSC certified. FSC certified wood products have a cost premium which resulted a slight cost increase.

4.2.26.1. Indoor Environmental Quality. This category includes measures related to indoor air quality and occupant comfort.

4.2.27. Prerequisite 1 and Credit 2, Ventilation

The projects shall provide 30% above the minimum rates required by ASHRAE 62-1 2007 standard (USGBC, 2009). The mechanical ventilation systems and air handling equipment of the project are designed according to this requirement from the early design. Thus, no additional costs are associated with the credit.

4.2.28. Prerequisite 2, Environmental Tobacco Smoke Control

In order to comply with the credit smoking is prohibited in all areas inside the building similar to the Turkish regulations . Additionally, the prerequisite requires smoking prohibition outside the building within 8 meters of entries, outdoor air intakes and operable windows. Since the site of the building is small, smoking is prohibited in all site. This practice didn't create any additional costs.

4.2.29. Credit 1, Outdoor Air Delivery Monitoring

The credit requires installation of permanent monitoring systems which generate an alarm when airflow values or carbon dioxide (CO2) levels vary by 10% or more from the design values. The alarm should trigger via either a building automation system alarm to the building operator or a visual or audible alert to the building occupants (USGBC, 2009). The project has placed direct airflow measurement devices on each air handling unit and connected to the central building automation system in order to comply with the credit. Additionally, CO2 sensors are placed in densely occupied spaces such as conference room and meeting rooms. These units resulted in a fixed cost increase for the project.

4.2.30. Credit 3.1, Construction Indoor Air Quality Management Plan - During Construction

An indoor air quality management plan for construction phase is developed and implemented. The plan includes measures such as protection of ductwork and air handling equipment from dust, local temporary exhaust during dust creating indoor construction activities, controlling pollution of indoor spaces, protection of sensitive materials, preventing odor and other air contaminants during construction, storing of chemicals in a separate and closed area (USGBC, 2009). These practices do not require additional costs but a good management and regular monitoring. Applied measures are photographed and documented for LEED certification. A sample photograph of ductwork protection can be seen in figure 4.48

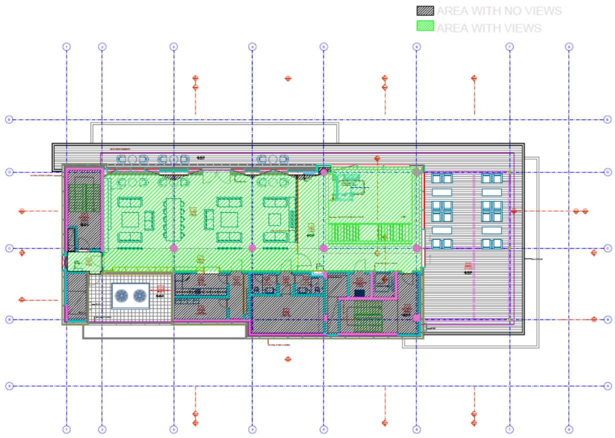

Figure 4.42. Sealing ductwork.

4.2.31. Credit 3.2, Construction Indoor Air Quality Management Plan - After Construction

The intent of this credit to ensure that the building is completely cleaned after construction phase before occupancy (USGBC, 2009). The building is flushed out with air to avoid any contaminants indoors. A minimum volume of 4500 m3 fresh air per m^2 is provided with the air handling units before the occupancy began. The air handling units ran full capacity for 18 days to provide this amount of fresh air to the building. After the flush out is completed the building indoor air was totally refreshed.

4.2.32. Credit 4.1, Low - Emitting Materials - Adhesives and Sealants

All adhesives and sealants used on the interior of the building should comply with the South Coast Air Quality Management District (SCAQMD) Rule ≠1168 according to LEED reference guide (USGBC, 2009). The products which are compliant with the ruling are available in the Turkish market. The requirements are added into the contractor's specifications in the project. Thus, the additional costs created are unknown but it is assumed to be negligible.

4.2.33. Credit 4.2, Low - Emitting Materials - Paints and Coatings

Paints and coatings used on the interior of the building must comply with the Green Seal Standard GS-11, Green Seal Standard GC-03 and South Coast Air Quality Management District (SCAQMD) Rule 1113 (USGBC, 2009). The requirements are added into the contractor's specifications in the project. Thus, the additional costs created are unknown but it is assumed to be negligible. The manufacturer specifications of the products are collected during the construction phase and documented for LEED certification.

4.2.34. Credit 4.3, Low - Emitting Materials - Flooring Systems

The credit aims to reduce the quantity of indoor air contaminants emitted by flooring materials that are odorous, irritating and/or harmful to the well-being of construction workers and occupants. LEED has specified requirements for different flooring types (USGBC, 2009). The project installed natural stone flooring and carpets that are Green Label certified. The selection of Green Label certified carpets didn't create significant cost increase according to contractors opinion.

4.2.35. Credit 5, Indoor Chemical and Pollutant Source Control

To capture dirt and particulates entering the building through pedestrian entrances, entryway mats with a length of 3 meters are installed on every entrance. Some building zones may contain hazardous gases and chemicals such as parking garages and housekeeping rooms. These zones are sufficiently exhausted and negative pressure is created to avoid any leakage to other zones. Additionally, self-closing doors are installed. The air handling units which derive outdoor air to the building zones have filtration media with a class of F7 by CEN Standard EN 779: 2002. The mechanical drawings and photographs are documented for LEED certification.

4.2.36. Credit 6.1, Controllability of the Systems - Lighting

The intent of this credit is to provide a high level of lighting system control by individual occupants or groups in multi-occupant spaces and promote their productivity, comfort and well-being. Individual lighting controls such as desk lighting are provided for 90% of the building occupants to enable adjustments to suit individual task needs and preferences (USGBC, 2009).

4.2.37. Credit 6.2, Controllability of the Systems - Thermal Comfort

The intent of the credit is to provide thermal comfort control by individual occupants or groups in multi-occupant spaces (USGBC, 2009). Individual comfort controls are provided for minimum 50% of the building occupants. The project includes thermostat controls for each room and additionally operable windows. Thus, the credit is taken without an effort.

4.2.38. Credit 7.1, Thermal Comfort - Design

The intent of this credit is to provide a comfortable thermal environment that promotes occupant productivity and well-being (USGBC, 2009). Heating, ventilating and air conditioning (HVAC) systems are designed to meet ASHRAE 55-2004 criteria which specifies thermal environmental conditions for human occupancy such as radiant temperature, humidity ratio and indoor air speed. The mechanical design team provided documentation that shows the compliance with the ASHRAE 55-2004.

4.2.39. Credit 7.2, Thermal Comfort - Verification

In this credit, it is aimed to assess thermal comfort of building occupants (USGBC, 2009). A thermal comfort survey is prepared to be conducted for the building occupants. It didn’t create any additional costs.

4.2.40. Credit 8.2, Daylight and Views - Views

The compliance to the outside views credit is shown via the building floor plans and sections. A sample floor plan documented to LEED can be seen in Figure 4.43. The green hatched zones have views to the outside and red hatched zones do not have view to the outside. This credit didn't require any changes in the existing architectural design.

Figure 4.43. Ground floor plan showing views to outside.

4.2.41. Credit 1, Innovation in Design

Innovative performance is achieved by reducing the mercury content of the lighting fixtures. The overall average mercury content in lamps are limited to 90 pictograms per lumen-hour. This is achieved by selecting LED lamps which do not contain mercury or low mercury florescent lamps. The list of purchased lamps is documented for LEED certification. This strategy didn't create additional costs since LED lamps are already selected to increase efficiency.

Exceptional performance is achieved in three credits where the required LEED threshold is doubled by the project (USGBC, 2009). These are Water Efficiency Credit

3 Water Use Reduction, Materials and Resources Credit 4 Recycled Content and Materials and Resources Credit 5 Regional Materials. These performance credits are achieved without an effort.

4.2.42. Credit 2, LEED Accredited Professional

In order to achieve this credit at least one principal participant of the project team shall be a LEED Accredited Professional (USGBC, 2009). The project worked with a LEED consultancy company which has an assigned LEED AP for the project. LEED AP is included in the project from the early design to completion. LEED consultancy fees are included in the project as a fixed cost.

4.2.43. Credit 1, Regional Prioritye

This credit aims projects to provide an incentive for the achievement of credits that address geographically-specific environmental priorities. LEED specified some credits to be regionally more important than others and these credits give additional points if achieved. For Turkey, credits Energy and Atmosphere Credit 1 Energy Performance, Energy and Atmosphere Credit 3 Enhanced Commissioning, Water Efficiency Credit 1 Water Efficient Landscaping, Water Efficiency Credit 3 Water Use Reduction are selected for regional priority. This project achieved these credits and also regional priority credit by itself (USGBC, 2009).

4.2.44. Impact on Project Budget

In the previous chapter the green building implementation of each credit is explained and it is stated if they create additional costs or not. In this chapter, the additional costs are explained. The associated costs for each credit are investigated during the research with interviews and examinations of documents.

In this study, the costs are categorized in two ways. Firstly, the costs are categorized as hard and soft costs. Hard costs are resulted from purchases of additional or more expensive materials and equipment, physical implementation of green building strategies and associated labor costs. Soft costs include LEED consultancy fees, energy modeling fees, LEED certification fees and costs related to additional paperwork.

Secondly, it is found out that the costs can be classified in four categories: 1) Low size-sensitive costs 2) High size-sensitive costs 3) Costs depending the concept design 4) Negligible cost. Low size-sensitive costs are costs that have a minimum value and do not change significantly with the project size. These can also be considered as fixed costs. High size sensitive costs mainly depend on the project size and they can be considered as fixed costs per area. These costs can vary from zero to high values. Costs depending concept design are mostly depended on the project decisions and conditions. Some projects can comply with credits without any cost or any effort where some projects may result in high cost increase. Lastly, no cost credits are credits that can be achieved in almost all projects without cost increase independent from design.

Credits that created additional costs are explained below:

4.2.45. Sustainable Sites Credit 4.2, Alternative

Transportation-Bicycle Storage and Changing Rooms In order to comply with the credit 10 bicycle racks and 2 showers are added into the project. Estimate cost for the bicycle racks, shower and changing rooms are estimated to be $5,000. This item is categorized as high size-sensitive hard cost.

4.2.46. Sustainable Sites Credit 6.1, Stormwater Design - Quantity Control

Rainwater collection is implemented in addition to grey water system in order to achieve this credit and also reduce the water consumption. The credit could be achieved without cost if it had sufficient green area. Additional plumbing and water tank for rainwater collection resulted in a cost increase of $5,000. This item is categorized as concept design depended hard cost.

4.2.47. Sustainable Sites Credit 7.2, Heat Island Effect - Roof

The credit requires installing roofing material with high reflective properties or green roofing. Both of the strategies are implemented in the project. Light colored reflective membrane is implemented which doesn't create a cost difference. Green roof with an area of 30 m^2 is implemented with sedum type short plantation. The cost increase resulted from green roof is \$1,500. This item is categorized as concept design depended hard cost.

4.2.48. Water Efficieny Prerequisite and Credits, Water Use Reduction

In order to achieve maximum water efficiency and achieve all points in this category, the project implemented grey water re-use system. The water collected from lavatories and showers are treated and used in water closets and urinals. The system required installation of additional plumbing, water tanks and treatment equipment. The estimated cost of this system is \$20,000. This item is categorized as concept design depended hard cost.

4.2.49. Energy and Atmosphere Prerequisite 1 and Credit 3, Commissioning of Building Energy Systemse

Commissioning of energy related systems is conducted by a third party company. The services the commissioning company provided includes; review of the project compliance with owner's project requirements and the basis of design in terms of commissioning; training of the team and operational personnel in the equipment and building management systems, witness and complete these training as necessary; control and review of contractor submittals; implementing performance tests; preparation of a manual for operation personnel; conduction of a seasonal commissioning within nine months; preparation of the final commissioning report. The fee of the company is \$25,000.

4.2.50. Energy and Atmosphere Prerequisite 2 and Credit 1, Energy Performance

The costs related to the energy performance is not easy to evaluate since there are many factors affecting the performance of a building such as orientation, architecture, envelope properties, mechanical and lighting systems. Some buildings may need huge changes and a lot of effort to achieve this credit and some buildings may achieve the credit without effort. It is mostly related on the concept design.

In this project, the team aimed to achieve an energy efficient from the beginning of the design. The most important and costly strategy to increase energy efficiency is the underground labyrinth. In order to build the labyrinth an additional basement floor is built and related ventilation equipment is installed. The total cost of the labyrinth strategy is estimated to be $115,000. Besides, slab heating and cooling strategy required additional ductwork in the concrete. The additional cost of slab cooling and heating is estimated to be $35,000.

Energy simulation is conducted to calculate the energy performance and LEED points of the building. A consultancy company specialized in energy simulation is hired for the energy simulation work of the project. The fee of the company is $5,000. This item is categorized as concept design depended hard cost and soft cost considering the energy modeling fee.

4.2.51. Energy and Atmosphere Credit 2, Renewable Energy

The implementation of the photovoltaic panels and solar water heaters with a total capacity of 22 kW resulted in a cost increase of $28,000. The panels produce 30,000 kWh of energy annually according to energy simulation results. The electricity price is taken as 0,13 $/kWh in LEED calculations and the annual savings is calculated as $3,900. This item is categorized as high size-sensitive hard cost.

4.2.52. Materials and Resources Credit 7, Certified Wood

Forest Stewardship Council (FSC) certified wood is preferred during wood purchasing. Only the wood terraces are chosen FSC certified. It is concluded that FSC certified wood is approximately $2/m^2 more expensive than not certified wood with same properties. The project had 200 m^2 of wood installation. It resulted a cost increase of $400. This item is categorized as high size-sensitive hard cost.

4.2.53. Indoor Environmental Quality Credit 1, Outdoor Air Delivery Monitoring

In order to comply with the credit outdoor air flow measurement devices are added on every air handling unit in the building. The devices are connected with the building automation system which was already included in the project. Additionally, three CO2 sensors are installed in densely occupied spaces such meeting rooms and conference room. Cost of the air flow measurement devices is $600 (2 units x $300) and CO2 sensors is $600 (3 units x $200). This item is categorized as high size-sensitive hard cost.

4.2.54. Indoor Environmental Quality Credit 6.1, Controllability of the Systems- Lighting

The credit requires to have desk lighting in the open office work stations. Desk lamps are added to the project to comply with the credit. The additional cost is $850 (17 desk lamps x $50). This item is categorized as high size-sensitive hard cost.

4.2.55. LEED Consultancy Fees

The project hired a LEED consultancy company for the whole certification process. The company was available from the beginning of the design until the occupancy and managed the LEED certification. The services the LEED consultancy company provided includes; preparation of LEED documentation and sustainability charrette, establishing project goals and assigning roles, technical consultancy for project teams about sustainability practices and energy efficiency, supervision of construction activities, documentation and achievement of certification, support for green marketing. The fee of the company is \$30,000.

4.2.56. LEED Certification Fees

LEED certification fees which include registration fee, design review fee and construction review fee are paid to the GBCI. The fees are calculated according to building floor area. A discount is applicable for USGBC premium members. The fees can be seen in Table 4.8. The sum of fees this project is \$4,000. Overall, a green building cost increase of \$277,950 which is 3.97% of total budget and $\$55/m^2$ is estimated. All credits and related costs are summarized in Table 4.2.56. On the table, it can be seen that costliest items are energy performance improvement, renewable energy production, commissioning process, higher water efficiency and LEED consultancy services.

Table 4.22. LEED Costs of Case 2.

Credit Number/Name		Cost Type 1	Cost Type 2	Implemented Cost Items	Costs (USD)
Sustainable Sites					
Prereq 1	Construction Activity Pollution Prevention	Hard Cost	High Size-sensitive costs	Requirements mentioned in contractor's specifications. No additional costs created due low size.	0
Credit 1	Site Selection	No cost	No cost	The site meets requirements. No costs are involved.	0
Credit 2	Development Density and Community Connectivity	No cost	No cost	The site meets requirements. No costs are involved.	0
Credit 4.1	Alternative Transportation-Public Transportation Access	No cost	No cost	The site meets requirements. No costs are involved.	0
Credit 4.2	Alternative Transportation-Bicycle Storage and Changing Rooms	Hard Cost	High Size-sensitive costs	10 bicycle racks and construction of 2 shower and changing rooms	5000
Credit 4.3	Alternative Transportation-Low-Emitting and Fuel-Efficient Vehicles	Hard Cost	High Size-sensitive costs	No significant cost because of low size	0
Credit 4.4	Alternative Transportation-Parking Capacity	Hard Cost	High Size-sensitive costs	No significant cost because of low size	0
Credit 5.2	Site Development-Maximize Open Space	Hard Cost	Costs depending concept design	Project complies with negligible effort.	0
Credit 6.1	Stormwater Design-Quantity Control	Hard Cost	Costs depending concept design	Rainwater collection from roof in addition to grey water treatment.	5000
Credit 7.1	Heat Island Effect-Non-roof	Hard Cost	Costs depending concept design	Project complies with negligible effort.	0
Credit 7.2	Heat Island Effect-Roof	Hard Cost	Costs depending concept design	Cost of green roof construction (30 m^2)	1800
Water Efficiency					
Prereq 1	Water Use Reduction-20% Reduction	Hard Cost	Costs depending concept design	Rainwater and grey water capture , treatment and re-use. Additional plumbing work, water tanks and membrane filter system.	20000
Credit 1	Water Efficient Landscaping	Hard Cost	Costs depending concept design	Grey water re-use mentioned in previous credit.	0
Credit 2	Innovative Wastewater Technologies	Hard Cost	Costs depending concept design	Grey water re-use mentioned in previous credit.	0
Credit 3	Water Use Reduction	Hard Cost	Costs depending concept design	Grey water re-use mentioned in previous credit.	0

Table 4.22. LEED Costs of Case 2 (cont.).

Credit Number/Name		Cost Type 1	Cost Type 2	Implemented Cost Items	Costs (USD)
Energy and Atmosphere					
Prereq 1	Fundamental Commissioning of Building Energy Systems	Soft Cost	Low size-sensitive Costs	Commissioning is conducted by a third party company. Fee of the company: 25,000 USD	25000
Prereq 2	Minimum Energy Performance	Soft and Hard Cost	Costs depending concept design	Construction of labyrinth system Additional slab cooling system Energy modeling consultancy service	Hard: 150000 Soft: 5000
Prereq 3	Fundamental Refrigerant Management	No cost	No cost	Project complies with negligible effort.	0
Credit 1	Optimize Energy Performance	Soft and Hard Cost	Costs depending concept design	Cost is given in EAp2	0
Credit 2	Renewable Energy	Hard Cost	High size-sensitive costs	Installation of photovoltaic panels and water heating solar panels	28000
Credit 3	Enhanced Commissioning	Soft Cost	Low size-sensitive costs	Cost is given in EAp1	0
Credit 4	Enhanced Refrigerant Management	Hard Cost	No cost	Project complies with negligible effort.	0
Credit 5	Measurement and Verification	Hard Cost	Costs depending concept design	Project complies with negligible effort.	0

Table 4.22. LEED Costs of Case 2 (cont.).

Credit Number/Name		Cost Type 1	Cost Type 2	Implemented Cost Items	Costs (USD)
Materials and Resources					
Prereq 1	Storage and Collection of Recyclables	Hard Cost	High size-sensitive costs	Recyle bins are provided without significant cost due to low size.	0
Credit 2	Construction Waste Management	No cost	No cost	Complied with negligible effort.	0
Credit 4	Recycled Content	No cost	No cost	Project complies with negligible effort.	0
Credit 5	Regional Materials	No cost	No cost	Project complies with negligible effort.	0
Credit 6	Certified Wood	Hard Cost	High size-sensitive costs	FSC certified wood is preferred during wood purchasing. 500 m^2 of wood, cost increase apx. 3 $\$/m^2$	1500
Indoor Environmental Quality					
Prereq 1	Minimum Indoor Air Quality Performance	No cost	No cost	Project complies the credit without cost.	0
Prereq 2	Environmental Tobacco Smoke (ETS) Control	No cost	No cost	No costs	0
Credit 1	Outdoor Air Delivery Monitoring	Hard Cost	High size-sensitive costs	Addition of outdoor air flow measurement and CO2 sensors	1500
Credit 2	Increased Ventilation	No cost	No cost	Project complies with negligible effort..	0
Credit 3.1	Construction Indoor Air Quality Management Plan-During Construction	No cost	No cost	The requirements are added into the contractor's specifications. Related costs are unknown but it is assumed negligible	0

Table 4.22. LEED Costs of Case 2 (cont.).

Credit Number/Name		Cost Type 1	Cost Type 2	Implemented Cost Items	Costs (USD)
Credit 3.2	Construction Indoor Air Quality Management Plan-Before Occupancy	No cost	No cost	The requirements are added into the contractor's specifications. Related costs are unknown but it is assumed negligible	0
Credit 4.1	Low-Emitting Materials-Adhesives and Sealants	No cost	No cost	The requirements are added into the contractor's specifications. Related costs are unknown but it is assumed negligible	0
Credit 4.2	Low-Emitting Materials-Paints and Coatings	No cost	No cost	The requirements are added into the contractor's specifications. Related costs are unknown but it is assumed negligible	0
Credit 4.3	Low-Emitting Materials-Flooring Systems	Hard Cost	Costs depending concept design	Natural stone flooring complies with the credit.	0
Credit 5	Indoor Chemical and Pollutant Source Control	Hard Cost	High size-sensitive costs	Additional entry mats are put in three entrances.	300
Credit 6.1	Controllability of Systems - Lighting	Hard Cost	Costs depending concept design	Additional desk lighting for 17 workstations	850
Credit 6.2	Controllability of Systems - Thermal Comfort	Hard Cost	Costs depending concept design	Project complies with negligible effort.	
Credit 7.1	Thermal Comfort-Design	No cost	No cost	Project complies with negligible effort.	0
Credit 7.2	Thermal Comfort-Verification	Hard Cost	Costs depending concept design	Project complies with negligible effort.	0
Credit 8.2	Daylight and Views-Views	Hard Cost	Costs depending concept design	Project complies with negligible effort.	0

Table 4.22. LEED Costs of Case 2 (cont.).

Credit Number/Name		**Cost Type 1**	**Cost Type 2**	**Implemented Cost Items**	**Costs (USD)**
Innovation and Design					
Credit 1	Innovation in Design: Specific Title	No cost	No cost	Project complies with negligible effort.	0
Credit 2	LEED Accredited Professional	Soft Cost	Low size-sensitive costs	Included in LEED consultancy fees	0
Regional Priority					
Credit 1	Regional Priority: Specific Credit	No cost	No cost	Project complies with negligible effort.	0
LEED Certification Fees		Soft Cost	High size-sensitive costs	Calculated by floor area	4000
Consultancy Fees		Soft Cost	Low size-sensitive costs	LEED consultancy service costs	30000
Total cost (USD)					**277950**

4.2.57. Case 3, Bikur BAB Office

4.2.57.1. General Information. Bikur BAB Office is a core&shell building developed by Bikur Yapi Company. It is located in Kagithane, Istanbul with a construction area of 9,000 m^2. The building has 9 above ground floors rented as office, ground floor rented as retail area and 2 below ground floors designated as parking. The building is located on a site which is 2,300 m^2. The site contains parking entrance, green area and plaza areas for pedestrians. The project has achieved LEED - Gold certification in 2015. The project budget is approximately 7 million U.S. dollars according to LEED submission documents. The project team can be seen in Table 4.23 and the site plan is shown in Figure 4.45.

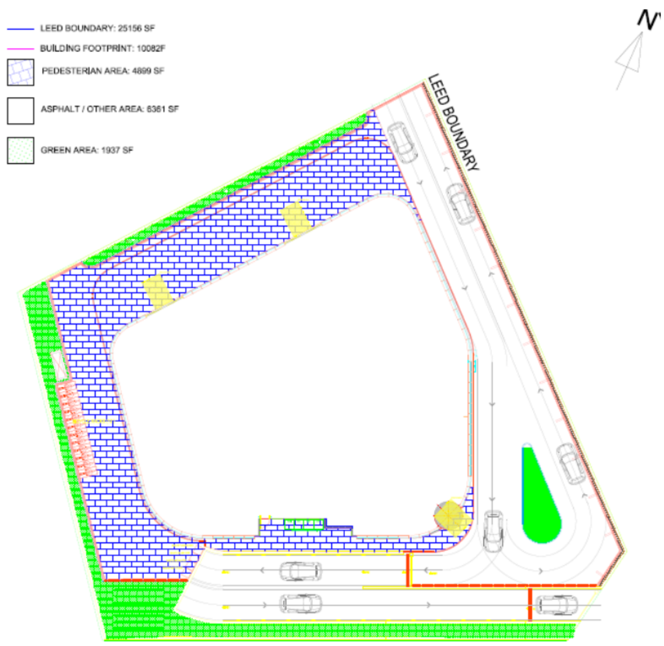

Figure 4.44. Outside view of Case 3.

Table 4.23. Project Team of Case 3.

Project Team	**Company**
Architectural Design	Kreatif Design Office
Mechanical Design	Dinamik Engineering
Electrical Design	Enkom Engineering
General Contractor	Bikur Yapi

Figure 4.45. Site plan of Case 3.

Figure 4.46. 3D render of Case 3.

4.2.58. Green Building Implementation

The project utilized different green building strategies according to LEED reference guide. These strategies are decided in the early design aiming to maximize LEED points and minimize the initial costs. The project earned 60 points out of 110 points of LEED and achieved LEED Gold certification. The list of achieved LEED criteria is given in Table 4.2.58. Criteria that the project implemented are explained in detail in this chapter under each category. Requirements are shortly described according to USGBC (2009) LEED Reference Guide and implementation to fulfil the requirement is explained according to project documents and interviews with project responsible.

Table 4.24. LEED scorecard of Case 3.

Sustainable Sites		**Possible Points**	**Achieved Points**
Prereq 1	Construction Activity Pollution Prevention	Prerequisite	
Credit 1	Site Selection	1	1
Credit 2	Development Density and Community Connectivity	5	5
Credit 3	Brownfield Redevelopment	1	0
Credit 4.1	Alternative Transportation-Public Transportation Access	6	6
Credit 4.2	Alternative Transportation-Bicycle Storage and Changing Rooms	2	2
Credit 4.3	Alternative Transportation-Low-Emitting and Fuel-Efficient Vehicles	3	3
Credit 4.4	Alternative Transportation-Parking Capacity	2	2
Credit 5.1	Site Development-Protect or Restore Habitat	1	0
Credit 5.2	Site Development-Maximize Open Space	1	1
Credit 6.1	Stormwater Design-Quantity Control	1	0
Credit 6.2	Stormwater Design-Quality Control	1	0
Credit 7.1	Heat Island Effect-Non-roof	1	1
Credit 7.2	Heat Island Effect-Roof	1	1
Credit 8	Light Pollution Reduction	1	0
Credit 9	Tenant Design and Construction Guidelines	1	1
Water Efficiency			
Prereq 1	Water Use Reduction-20% Reduction	Prerequisite	
Credit 1	Water Efficient Landscaping	4	2
Credit 2	Innovative Wastewater Technologies	2	2
Credit 3	Water Use Reduction	4	4

Table 4.24. LEED scorecard of Case 3 (cont.).

Sustainable Sites		**Possible Points**	**Achieved Points**
Energy and Atmosphere			
Prereq 1	Fundamental Commissioning of Building Energy Systems	Prerequisite	
Prereq 2	Minimum Energy Performance	Prerequisite	
Prereq 3	Fundamental Refrigerant Management	Prerequisite	
Credit 1	Optimize Energy Performance	21	0
Credit 2	On-Site Renewable Energy	4	0
Credit 3	Enhanced Commissioning	2	0
Credit 4	Enhanced Refrigerant Management	2	2
Credit 5.1	Measurement and Verification-Base Building	3	3
Credit 5.2	Measurement and Verification-Tenant Submetering	3	3
Credit 6	Green Power	2	0
Materials and Resources			
Prereq 1	Storage and Collection of Recyclables	Prerequisite	
Credit 1	Building Reuse-Maintain Existing Walls, Floors, and Roof	5	0
Credit 2	Construction Waste Management	2	2
Credit 3	Materials Reuse	1	0
Credit 4	Recycled Content	2	2
Credit 5	Regional Materials	2	2
Credit 6	Certified Wood	1	1
Prereq 1	Minimum Indoor Air Quality Performance	Prerequisite	
Indoor Environmental Quality			
Prereq 2	Environmental Tobacco Smoke (ETS) Control	Prerequisite	
Credit 1	Outdoor Air Delivery Monitoring	1	1
Credit 2	Increased Ventilation	1	1
Credit 3	Construction Indoor Air Quality Management Plan-During Construction	1	1
Credit 4.1	Low-Emitting Materials-Adhesives and Sealants	1	0
Credit 4.2	Low-Emitting Materials-Paints and Coatings	1	1
Credit 4.3	Low-Emitting Materials-Flooring Systems	1	1
Credit 4.4	Low-Emitting Materials-Composite Wood and Agrifiber Products	1	0
Credit 5	Indoor Chemical and Pollutant Source Control	1	0
Credit 6	Controllability of Systems-Thermal Comfort	1	0
Credit 7	Thermal Comfort-Design	1	1
Credit 8.1	Daylight and Views-Daylight	1	1
Credit 8.2	Daylight and Views-Views	1	1

Table 4.24. LEED scorecard of Case 3 (cont.).

Sustainable Sites		**Possible Points**	**Achieved Points**
Innovation and Design			
Credit 1	Innovation in Design: Specific Title	5	4
Credit 2	LEED Accredited Professional	1	1
Regional Priority			
Credit 1	Regional Priority: Specific Credit	4	2
Total Points		**110**	**60**

4.2.58.1. Sustainable Sites. Sustainable sites category deals with the issues related to site location, its relation with surroundings and how the open space is designed.

4.2.59. Prerequisite 1, Construction Activity Pollution Prevention

An Erosion and Sedimentation Control (ESC) Plan is created and implemented for all construction activities. The plan conformed to the erosion and sedimentation requirements of the U.S. 2003 EPA Construction General Permit (USGBC, 2009). The site is closed with perimeter fencing. Perimeter fencing is implemented without any holes under or between to avoid any soil or dust escaping from the site. Geotextile is buried under the fencing to avoid soil flow after heavy rain.

4.2.60. Credit 1, Site Selection

The intent of this credit is to avoid the development of inappropriate sites and reduce the environmental impact from the location of a building on a site. The site contained an old building before and it doesn't qualify any of these options by itself. The credit is taken without any effort.

4.2.61. Credit 2 Development Density and Community Connectivity

A map of surroundings is prepared in order to show the building density in the community. Each number on the map presents a building block. The approximate floor and site area of each building block is documented. The map can be seen in

Figure 4.47. The project complied without effort.

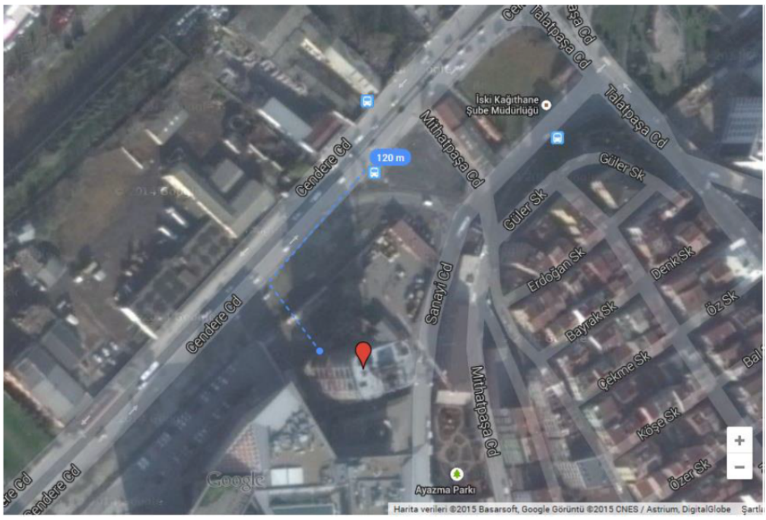

Figure 4.47. Development density map of Case 3.

4.2.62. Credit 4.1, Alternative Transportation - Public Transportation Access

The project complied with this credit since it is located on a main district and bus stations are located in close distance. A map showing the bus stops near the site is prepared as shown in Figure 4.48. The project complied without effort.

4.2.63. Credit 4.2, Alternative Transportation-Bicycle Storage and Changing Rooms

The bicycle racks are put on the open space and shower and changing facilities are deigned in the first basement for the use of occupants. Implementation of these facilities resulted in additional costs per unit area. It is estimated that 240 people will work in the building. Thus, 12 secure bicycle racks and 4 shower facilities are provided.

4.2.64. Credit 4.3, Alternative Transportation - Low - Emitting and Fuel - Efficient Vehicles

The capacity of the carpark is 52. 2 charging stations for electrical cars are provided in the carpark to comply with the credit. Charging stations resulted in a hard cost increase which is affected by project size.

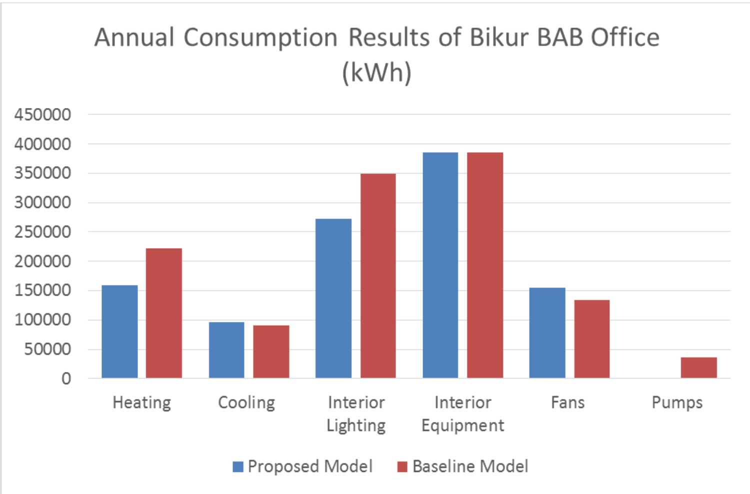

Figure 4.48. Transportation map of Case 3.

4.2.65. Credit 4.4, Alternative Transportation-Parking Capacity

The number of provided car park cannot exceed the minimum number given in the local regulation (USGBC, 2009). The capacity of the carpark is 52 where the car parking regulation of Istanbul requires 135 (one car park for 50 m^2 of office space). The credit is achieved without additional costs but it was depended on the concept architectural project.

4.2.66. Credit 5.2, Site Development - Maximize Open Space

The aim of this credit is to open space for the building users. 20% of total site area (including building footprint) should be landscaped or open to pedestrian access (USGBC, 2009). The project site has 650 m^2 of open space containing green and pedestrian area which is 26% of total site. The credit is achieved without additional costs but it was depended on the concept architectural project.

4.2.67. Credit 7.1, Heat Island Effect - Non - roof

In order to avoid heat island effect resulted on open spaces, LEED requires that 50% of car park should be underground or shaded. 100% of carpark is located under the buildings in the project. Thus, the credit is achieved without additional costs but it was depended on the concept architectural project.

4.2.68. Credit 7.2, Heat Island Effect - Roof

In order to avoid heat island effect resulted on roofs, roofing materials which have SRI values higher than 78 or green roofs should be installed on the roof. In this projects, white colored roofing membrane cover is implemented on the roof. White colored roofing membrane has an SRI of 102. Thus, the credit is achieved without additional costs but it was depended on the concept architectural project.

4.2.69. Credit 9, Tenant Design and Construction Guidelines

Tenant design and construction guideline and green lease for tenants are prepared. Green lease contains mandatory items of LEED which tenants must perform similar to the prerequisite items discussed in this section. The guideline is not mandatory but it instructs the tenants how to design their space in a more sustainable way. The guideline includes all the categories in LEED such as water efficient, energy efficiency and indoor environmental quality. This credit didn't result in additional cost.

4.2.69.1. Water Efficiency. This category evaluates the buildings domestic and landscaping water consumption.

4.2.70. Prerequisite 1, Credit 2 and Credit 3, Water Use Reduction

The project performed 44% better than the LEED baseline by selecting low consuming fixture equipment. The table 4.3 shows the consumption values and selected equipment. The project complies with the prerequisite, credit 2 and credit 3 by choosing these water fixtures. These fixtures can be found in the Turkish market and there is not a significant cost premium.

Table 4.25. Water fixtures of Case 3.

Fixture Type	**Baseline Consumption Value (EPA, 2009)**	**Installed Consumption Value**	**Unit**	**Brand**	**Model**
Water Closets	6,00	2,50 - 4,00	liter/flush	VITRA	740-1850-02
Lavotaries	2.00	2.00	liter/cycle	VITRA	A47008WS
Shower Head	9.50	6.00	liter/min	VITRA	AQUAMAX
Kitchen Sink	8.50	9.00	liter/min	VITRA	Minimax S Sink Mixer

4.2.71. Credit 1, Water Efficient Landscaping

The landscape is relatively small with an area of 180 m^2. It contains mainly shrubs and flowers. No turf grass is installed in the project which has the highest consumption value and most commonly used plant. Instead of turf grass, natural ground cover found in the region is implemented. The list of plants chosen in the project is shown in the Table 4.26. Automated drip irrigation system is implemented in the project instead of conventional sprinkler system. 60% reduction according to LEED baseline is achieved in irrigation consumption.

Table 4.26. Plants selected in Case 3.

Local Plant Name	**Latin Name**
Lelandi	Cuppressocyparis
Suber	Quercus Suber
Confetti	Abelia Grandiflora
Yonca	Trifolium Rapens

4.2.71.1. Energy and Atmosphere. Energy and Atmosphere category includes credits about maximizing energy efficiency, renewable energy production, energy monitoring and depletion of ozone layer.

4.2.72. Prerequisite 1, Commissioning of Building Energy Systems

In this project, commissioning is performed by the Bikur Yapi itself as a standard procedure. All process is reviewed by the commissioning agent assigned in Bikur. Energy management training and system manual are prepared for the personnel. This credit did not create additional costs.

4.2.73. Prerequisite 2, Energy Performance

This is the most important credit of the LEED certification with a total available points of 21. The intent of the credit is to establish the level of energy efficiency for the proposed building and systems to reduce environmental and economic impacts associated with excessive energy use. The energy efficiency of the building is measured by doing building energy modeling (USGBC, 2009). The energy modeling of the building is done using HAP software by the consultant company. The building passed the prerequisite efficiency ratio of 10% according to energy modeling results. The project did not implement additional strategies to increase energy efficiency. The design is not affected by the prerequisite since the threshold to pass the prerequisite is low.

The mechanical design is one of the most important aspect in energy efficiency.

The HVAC system of the proposed buildings is modeled using based on mechanical drawings and mechanical project report provided by mechanical group. The building contains VRF (Variable Refrigerant Flow) system for heating and cooling. Mechanical ventilation is done by heat recovery ventilators. Other energy efficiency measures are included in the tenant design guideline in order to advise tenants for higher energy efficiency.

Figure 4.49 shows the annual energy consumption results of different load types. Improvement is achieved in heating and interior lighting. Baseline model includes pumps because baseline system includes a FCU system. There is no improvement in cooling, fans and equipment loads such as receptacle, elevators, exhaust fans etc.

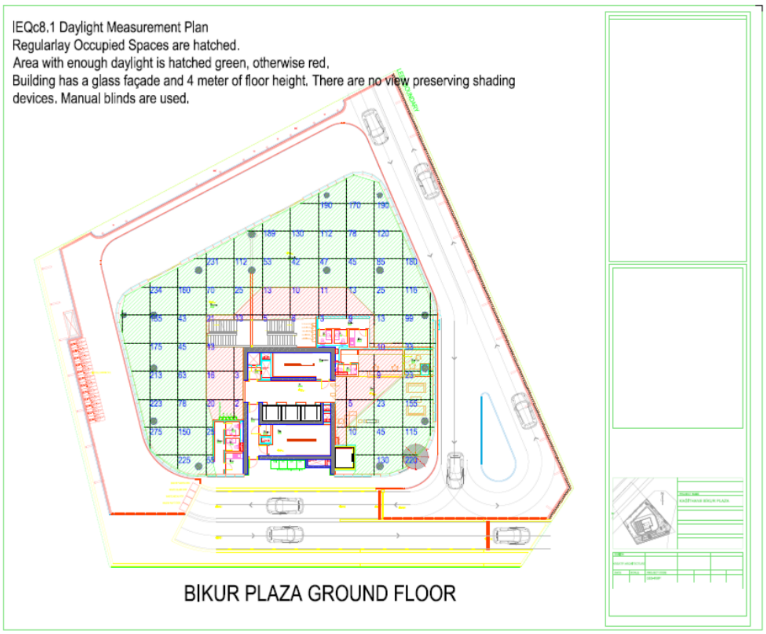

Figure 4.49. Detailed Modeling Results of Case 3.

4.2.74. Prerequisite 3 and Credit 4, Refrigerant Management

The type and amount of refrigerant gas of the installed systems are calculated in order to find ozone impact. In this project, R-410A type of refrigerant gas is used which complies with the credit requirement. There is not any additional costs for this credit.

4.2.75. Credit 5, Measurement and Verification

Metering equipment to measure energy use of cooling, heating and other electrical systems are installed on each tenant space and common areas. These meters are connected to a central automation system which monitors and reports the consumption results regularly. The performance of these systems are compared with predicted performance and broken down by component or system as appropriate. Any deficiencies will be investigated by the building management. Metering equipment and automation system was already planned in concept stage in this project. Thus, the costs are depended on the concept design.

4.2.75.1. Materials and Resources. Materials and resources category includes credits is mainly related to production construction materials and recycle opportunities.

4.2.76. Prerequisite 1, Storage and Collection of Recyclables

Recycle bins are for paper, glass, plastics and metals are located on the common areas next to elevators on every floor. Building management collects these bins every night and transfers to storage areas in the basements. Recyclable waste collection of the local municipality occurs twice a week. Recycling storage areas are located in the basement.

4.2.77. Credit 2, Construction Waste Management

Construction waste management plan is prepared by LEED consultant and contractor. The project diverted 75% of construction waste from landfill and delivered to recycle facilities. Waste types delivered to the recycling are steel, metals, concrete, paper and plastic packages. Recyclable materials are separated on the site and delivered to the recycling facilities by municipality. The costs are considered negligible.

4.2.78. Credit 4, Recycled Content

The project selected materials with recycled content for at least 20% of all construction materials based on cost in order to comply with the credit. Typically, new rebar used in reinforced concrete structure are produced from scrap iron collected from the region. It does have around 95% post-consumer content. Thus, for the reinforced concrete structures this credit is achieved without any costs.

4.2.79. Credit 5, Regional Materials

The project selected materials that are harvested and manufactured within 800 km for at least 20% of all construction materials based on cost in order to comply with the credit. In this project, raw materials of concrete are manufactured within 800 km distance. Manufacturer letters and explanatory documents are used for LEED documentation. As a result, 20% of all construction materials are regional.

4.2.79.1. Indoor Environmental Quality. This category includes measures related to indoor air quality and occupant comfort.

4.2.80. Prerequisite 1 and Credit 2, Ventilation

The projects shall provide 30% above the minimum rates required by ASHRAE 62-1 2007 standard (USGBC, 2009). The mechanical ventilation systems and air handling equipment of the project are designed according to this requirement from the early design. Thus, no additional costs are associated with the credit.

4.2.81. Prerequisite 2, Environmental Tobacco Smoke Control

In order to comply with this credit smoking is prohibited around the building within 8 meters of entrances. This practice didn't create any additional costs.

4.2.82. Credit 1, Outdoor Air Delivery Monitoringe

The project has placed direct airflow measurement devices on each air handling unit and connected to the central building automation system in order to comply with the credit. These units resulted in a fixed cost increase for the project.

4.2.83. Credit 3, Construction Indoor Air Quality Management Plan

An indoor air quality management plan for construction phase is developed and implemented. The plan includes measures such as protection of ductwork and air handling equipment from dust, local temporary exhaust during dust creating indoor construction activities, controlling pollution of indoor spaces, protection of sensitive materials, preventing odor and other air contaminants during construction, storing of chemicals in a separate and closed area (USGBC, 2009). These practices do not require additional costs but a good management and regular monitoring.

4.2.84. Credit 4.2, Low - Emitting Materials - Paints and Coatings

This credit limits the content of Volatile Organic Compound (VOC) value of the painting and coating products. The products which are compliant with the credit are available in the Turkish market. The requirements are added into the contractor's specifications in the project. Thus, the additional costs created are unknown but it is assumed to be negligible.

4.2.85. Credit 4.3, Low - Emitting Materials - Flooring Systems

This credit aims to reduce the amount of indoor air contaminants emitted by flooring materials that are odorous, irritating and/or harmful to the well-being of construction workers and occupants. LEED has specified requirements for different flooring types. The project installed natural stone flooring which doesn't emit any volatile organic compounds to the surrounding air (USGBC, 2009). Natural stone was already planned in the project. Thus, no additional costs is required for the project.

The manufacturer specifications of the products are collected during the construction phase and documented for LEED certification.

4.2.86. Credit 7, Thermal Comfort - Design

The mechanical design team provided documentation that shows the compliance with the ASHRAE 55-2004 thermal comfort standatd via the online CBE (Center for Built Environment) Thermal Comfort Tool.

4.2.87. Credit 8.1, Daylight and Views - Daylight

Daylight level measurements are made in order to prove the compliance with the LEED requirement of daylight levels. More than 75% of all regularly occupied spaces such as offices and retail areas achieve daylight illuminance levels of a minimum of 110 lux in a clear sky condition. The architectural design of the building was already compliant with the credit. Thus, no additional changes or costs are applicable for the credit. The measurements are done by the LEED consultant as part of their scope. A sample measurement plan is given in Figure 4.50. Green hatched area has sufficient daylight levels.

4.2.88. Credit 8.2, Daylight and Views - Views

90% of all regularly occupied areas should have outside views for this credit compliance (USGBC, 2009). The compliance is shown via the building floor plans and sections. A sample floor plan documented to LEED can be seen in Figure 4.51. The green hatched zones have views to the outside and red hatched zones do not have view to the outside. This credit didn't require any changes in the existing architectural design.

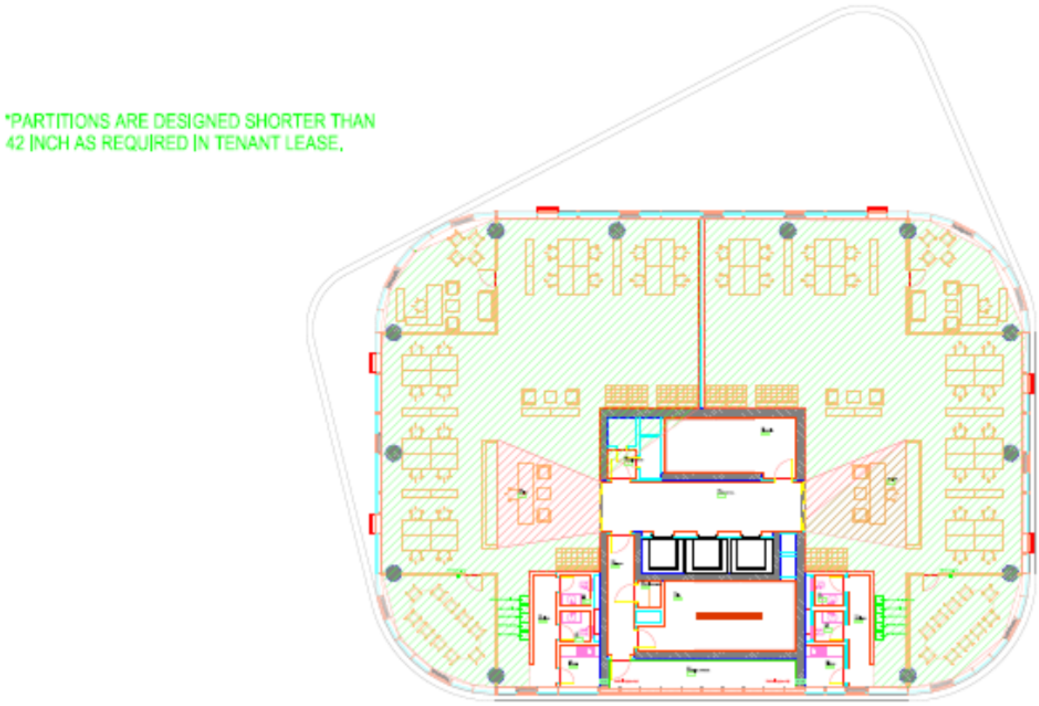

Figure 4.50. Daylight measurement plan of Case 3.

Figure 4.51. View to outside plan of Case 3.

4.2.89. Credit 1, Innovation in Design

Exceptional performance is achieved in three credits where the required LEED threshold is doubled by the project. These are Sustainable Sites Credit 2 Development

Density, Sustainable Sites Credit 4.1 Alternative Transportation and Materials and Resources Credit 5 Regional Materials. These performance credits are achieved without an effort (USGBC, 2009).

4.2.90. Credit 2, LEED Accredited Professional

In order to achieve this credit at least one principal participant of the project team shall be a LEED Accredited Professional (USGBC, 2009). The project worked with a LEED consultancy company which has an assigned LEED AP for the project. LEED AP is included in the project from the early design to completion. LEED consultancy fees are included in the project as soft cost.

4.2.91. Credit 1, Regional Priority

This credit aims projects to provide an incentive for the achievement of credits that address geographically-specific environmental priorities. This project earned two of four credits without an effort (USGBC, 2009).

4.2.92. Impact on Project Budget

In the previous chapter the green building implementation of each credit is explained and it is stated if they create additional costs or not. In this chapter, the additional costs are explained. The associated costs for each credit are investigated during the research with interviews and examinations of documents.

In this study, the costs are categorized in two ways. Firstly, the costs are categorized as hard and soft costs. Hard costs are resulted from purchases of additional or more expensive materials and equipment, physical implementation of green building strategies and associated labor costs. Soft costs include LEED consultancy fees, energy modeling fees, LEED certification fees and costs related to additional paperwork.

Secondly, it is found out that the costs can be classified in four categories: 1)

Low size-sensitive costs 2) High size-sensitive costs 3) Costs depending the concept design 4) Negligible cost. Low size-sensitive costs are costs that have a minimum value and do not change significantly with the project size. These can also be considered as fixed costs. High size sensitive costs mainly depend on the project size and they can be considered as fixed costs per area. These costs can vary from zero to high values. Costs depending concept design are mostly depended on the project decisions and conditions. Some projects can comply with credits without any cost or any effort where some projects may result in high cost increase. Lastly, no cost credits are credits that can be achieved in almost all projects without cost increase independent from design. Credits that created additional costs are explained below:

4.2.93. Sustainable Sites Credit 4.2, Alternative

Transportation-Bicycle Storage and Changing Rooms In order to comply with the credit 12 bicycle racks, 4 showers and changing rooms are added into the project. Estimate cost for the bicycle racks are $600 ($50 x 12). Estimated cost for shower and changing rooms are $4000 ($1000 x 4). Total cost of this credit is $4600. This is a hard cost and high size-sensitive cost since the required number of units increases with the building size.

4.2.94. Sustainable Sites Credit 4.3, Alternative

Transportation-Low-Emitting and Fuel-Efficient Vehicles 2 special charging stations for electrical cars are installed in the building. Cost of these units is $7000. This is a high size-sensitive hard cost.

4.2.95. Energy and Atmosphere Prerequisite 2, Energy Performance

The costs related to the energy performance is not easy to evaluate since there are many factors affecting the performance of a building such as orientation, architecture, envelope properties, mechanical and lighting systems. Some buildings may need huge changes and a lot of effort to achieve this credit and some buildings may achieve the credit without effort. It is mostly related on the concept design.

In this project, the building slightly passed the mandatory level of energy efficiency and it can be said that the building is significantly energy efficient. Additionally, the project team stated that there aren't any changes made in the design for the LEED purpose. The existing design of the project was capable to pass the mandatory limit. Thus, there aren't any hard costs related to energy efficiency. A consultancy company specialized in energy simulation is hired for the energy simulation work of the project. The fee of the company is \$20,000. This fee is considered as a concept design depending soft cost.

4.2.96. Materials and Resources Prerequisite 1, Storage and Collection of Recyclables

For the purpose of this credit four recycle bins are provided on every floor. The cost of the bins is \$1600 (40 bins x \$40). This item is categorized as high size-sensitive hard cost.

4.2.97. Indoor Environmental Quality Credit 1, Outdoor Air Delivery Monitoring

In order to comply with the credit outdoor air flow measurement devices are added on every air handling unit in the building. The devices are connected with the building automation system which was already included in the project. Cost of the air flow measurement devices is \$2500 (10 units x \$250). This item is categorized as high size-sensitive hard cost.

4.2.98. LEED Consultancy Fees

The project hired a LEED consultancy company for the whole certification process. The company was available from the beginning of the design until the occupancy and managed the LEED certification. The services the LEED consultancy company provided includes; preparation of LEED documentation and sustainability charrette, establishing project goals and assigning roles, technical consultancy for project teams about sustainability practices and energy efficiency, supervision of construction activities, documentation and achievement of certification, support for green marketing. The fee of the company is \$20,000. This item is categorized as low size-sensitive cost and soft cost.

4.2.99. LEED Certification Fees

Green Building Certification Institute (GBCI) is the only authorized institution by U.S. Green Building Council that provides LEED certification in the world. The institute reviews documentation provided by LEED consultants via an online system and awards the certification accordingly. LEED certification fees which include registration fee, design review fee and construction review fee are paid to the GBCI. The fees are calculated according to building floor area. A discount is applicable for USGBC premium members. The fees can be seen in Table 4.8. The sum of fees this project is \$5,200. This item is categorized as high size-sensitive soft cost. Overall, a green building cost increase of \$50,900 which is 0.72% of total budget and \$5.6/m^2 is estimated. All credits and related costs are summarized in Table 4.3.1. On the table, costliest items are energy performance, LEED consultancy services and electrical vehicle charging stations.

4.3. Case 4: Tupras R&D Management Building

4.3.1. General Information

Tupras Research and Development Management Building is an office building constructed in Tupras refinery, Kocaeli. It has construction area of 4,500 m^2. The building has 5 above ground floors which include mainly office area, conference room and restaurant. The building is located on a site which is 4,200 m^2. The site contains parking, green area and plaza areas for pedestrians. The project has achieved LEED - Gold certification in 2015. The project budget is approximately 5.5 million U.S. dollars according to LEED submission documents. The project team can be seen in Table 4.27 and the site plan is shown in Figure 4.52.

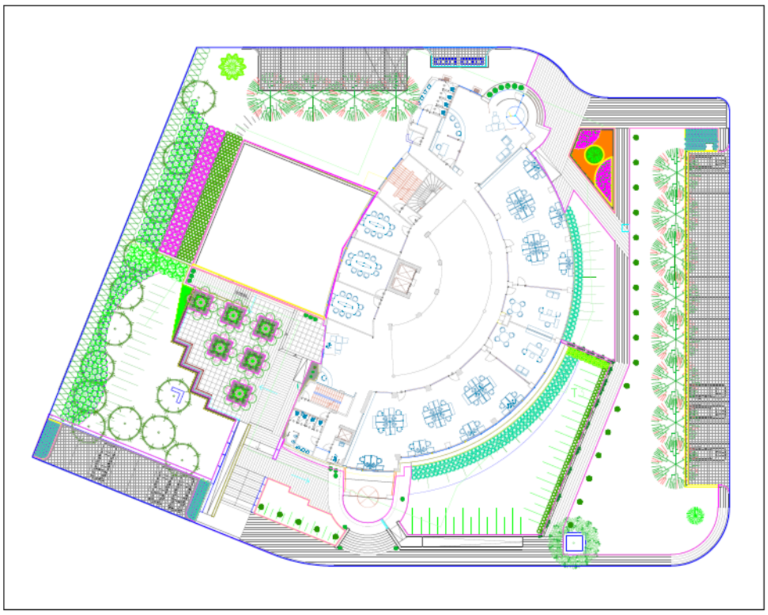

Figure 4.52. Outside view of Case 4.

Table 4.27. LEED Costs of Case 3.

Credit Number/Name		Cost Type 1	Cost Type 2	Implemented Cost Items	Costs (USD)
Sustainable Sites					
Prereq 1	Construction Activity Pollution Prevention	Hard Cost	High Size-sensitive costs	Negligible cost due to small size	0
Credit 1	Site Selection	No cost	No cost	The site meets requirements. No costs are involved.	0
Credit 2	Development Density and Community Connectivity	No cost	No cost	The site meets requirements. No costs are involved.	0
Credit 4.1	Alternative Transportation-Public Transportation Access	No cost	No cost	The site meets requirements. No costs are involved.	0
Credit 4.2	Alternative Transportation-Bicycle Storage and Changing Rooms	Hard Cost	High Size-sensitive costs	12 bicycle racks: 50x12 = 6000 USD 4 showers: 4x1000 = $4000	4600
Credit 4.3	Alternative Transportation-Low-Emitting and Fuel-Efficient Vehicles	Hard Cost	High Size-sensitive costs	2 Electrical charging stations: $7000	7000
Credit 4.4	Alternative Transportation-Parking Capacity	Hard Cost	High Size-sensitive costs	Negligible cost due to small size	0
Credit 5.1	Site Development-Protect or Restore Habitat	Hard Cost	Costs depending concept design	No cost: Already included in concept design	0
Credit 7.1	Heat Island Effect-Non-roof	Hard Cost	Costs depending concept design	No cost: Already included in concept design	0
Credit 7.2	Heat Island Effect-Roof	Hard Cost	Costs depending concept design	No cost: Already included in concept design	0

Table 4.27. LEED Costs of Case 3 (cont.).

Credit Number/Name		**Cost Type 1**	**Cost Type 2**	**Implemented Cost Items**	**Costs (USD)**
Credit 9	Tenant Design and Construction Guidelines	No Cost	No Cost	No cost	0
Water Efficiency					
Prereq 1	Water Use Reduction- 20% Reduction	Hard Cost	Costs depending concept design	The water fixtures are selected accordingly. No significant cost difference	0
Credit 1	Water Efficient Landscaping	Hard Cost	Costs depending concept design	Low water consuming plants are selected: No significant cost	0
Credit 2	Innovative Wastewater Technologies	Hard Cost	Costs depending concept design	The water fixtures are selected accordingly. No significant cost difference.	0
Credit 3	Water Use Reduction	Hard Cost	Costs depending concept design	The water fixtures are selected accordingly. No significant cost difference.	0
Prereq 1	Fundamental Commissioning of Building Energy Systems	Soft Cost	Low size-sensitive Costs	Commissioning is conducted by the developer team. No associated costs.	0

Table 4.27. LEED Costs of Case 3 (cont.).

Credit Number/Name		Cost Type 1	Cost Type 2	Implemented Cost Items	Costs (USD)
Energy and Atmosphere					
Prereq 2	Minimum Energy Performance	Soft Cost	Costs depending concept design	A consultancy company for energy simulation is hired for the work: Apx. 10,000 $	10000
Prereq 3	Fundamental Refrigerant Management	No cost	No cost	Project complies the credit with negligible effort.	0
Credit 4	Enhanced Refrigerant Management	Hard Cost	No cost	Project complies with negligible effort.	0
Credit 5.1	Measurement and Verification-Base Building	Hard Cost	Costs depending concept design	No cost: Already included in concept design	0
Credit 5.2	Measurement and Verification-Tenant Submetering	Hard Cost	Costs depending concept design	No cost: Already included in concept design	0
Materials and Resources					
Prereq 1	Storage and Collection of Recyclables	Hard Cost	High size-sensitive costs	Recyle bins are provided on every floor. 0 x 4 = 40 bins 40 x 40 = 1600 USD	1600

Table 4.27. LEED Costs of Case 3 (cont.).

Credit Number/Name		Cost Type 1	Cost Type 2	Implemented Cost Items	Costs (USD)
Credit 2	Construction Waste Management	No cost	No cost	Recycable materials are seperated on the site and delivered to the recycling facilities by municipality. Negligible cost.	0
Credit 4	Recycled Content	No cost	No cost	Project complies with negligible effort.	0
Credit 5	Regional Materials	No cost	No cost	Project complies with negligible effort.	0
Indoor Environmental Quality					
Prereq 1	Minimum Indoor Air Quality Performance	No cost	No cost	Project complies with negligible effort.	0
Prereq 2	Environmental Tobacco Smoke (ETS) Control	No cost	No cost	No costs	0
Credit 1	Outdoor Air Delivery Monitoring	Hard Cost	High size-sensitive costs	Addition of outdoor air flow measurement devicefor 5 air handling units. 10 x 250 = $2500	2500
Credit 2	Increased Ventilation	No cost	No cost	Project complies with negligible effort.	0

Table 4.27. LEED Costs of Case 3 (cont.).

Credit Number/Name		**Cost Type 1**	**Cost Type 2**	**Implemented Cost Items**	**Costs (USD)**
Credit 3	Construction Indoor Air Quality Management Plan-During Construction	No cost	No cost	The requirements are added into the contractor's specifications. Related costs are unknown but it is assumed negligible	0
Credit 4.2	Low-Emitting Materials-Paints and Coatings	No cost	No cost	The requirements are added into the contractor's specifications. Related costs are unknown but it is assumed negligible	0
Credit 4.3	Low-Emitting Materials-Flooring Systems	Hard Cost	Costs depending concept design	Natural stone flooring complies with the credit.	0
Credit 7	Thermal Comfort-Design	No cost	No cost	Project complies with negligible effort.	0
Credit 8.1	Daylight and Views-Daylight	Hard Cost	Costs depending concept design	Project complies with negligible effort.	0
Credit 8.2	Daylight and Views-Views	Hard Cost	Costs depending concept design	Project complies with negligible effort.	0
Innovation and Design					
Credit 1	Innovation in Design: Specific Title	No cost	No cost	Project complies with negligible effort.	0
Credit 2	LEED Accredited Professional	Soft Cost	Low size-sensitive costs	Included in LEED consultancy fees	0

Table 4.27. LEED Costs of Case 3 (cont.).

Credit Number/Name		**Cost Type 1**	**Cost Type 2**	**Implemented Cost Items**	**Costs (USD)**
Regional Priority					
Credit 1	Regional Priority: Specific Credit	No cost	No cost	Project complies with negligible effort.	0
LEED Certification Fees		Soft Cost	High size-sensitive costs	Calculated by floor area	5200
Consultancy Fees		Soft Cost	Low size-sensitive costs	LEED consultancy service costs	20000
Total cost (USD)					**50900**

Table 4.27. Project Team of Case 4.

Project Team	Company
Architectural Design	Paska Architecture
Mechanical Design	Labcon Engineering
Electrical Design	Labcon Engineering
General Contractor	Ark Construction

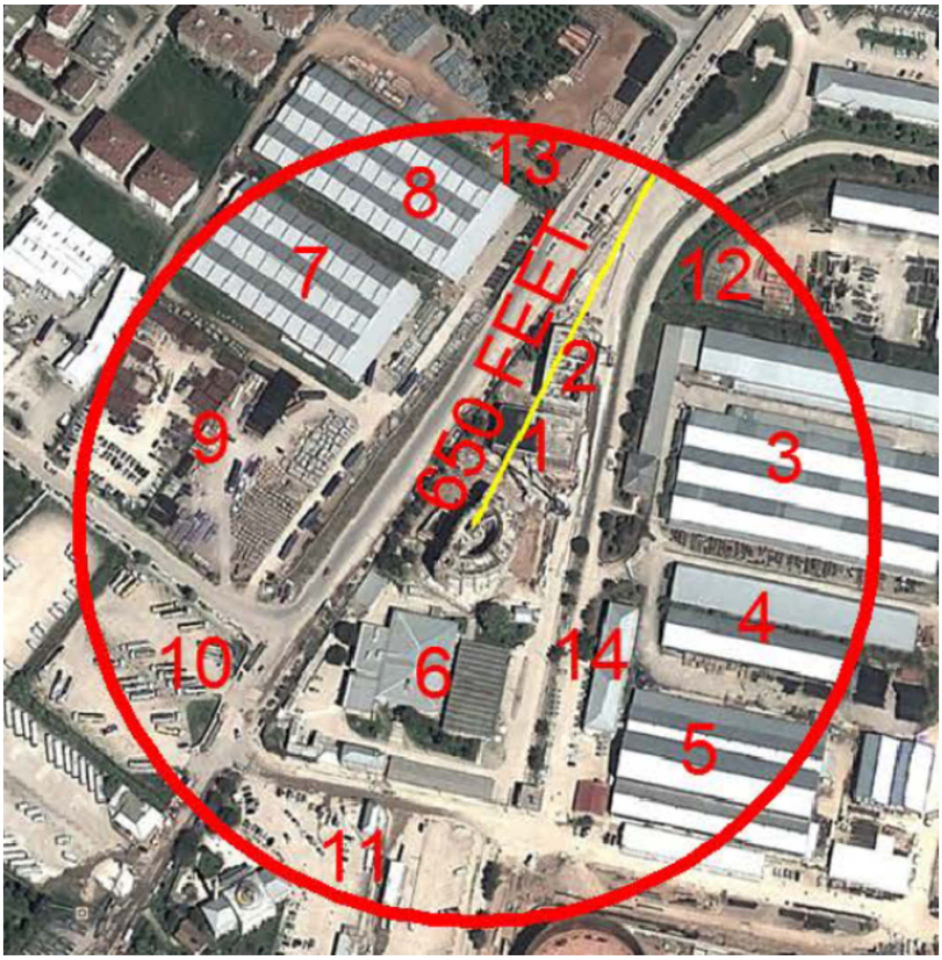

Figure 4.53. Site plan of Case 4.

4.3.2. Green Building Implementation

The project utilized different green building strategies according to LEED reference guide. These strategies are decided in the early design aiming to maximize LEED points and minimize the initial costs. The project earned 60 points out of 110 points of LEED and achieved LEED Gold certification. The list of achieved LEED criteria is given in Table 4.3.2. Criteria that the project implemented are explained in detail in this chapter under each category. Requirements are shortly described according to USGBC (2009) LEED Reference Guide and implementation to fulfil the requirement is explained according to project documents and interviews with project responsible.

Table 4.28. LEED scorecard of Case 4.

Sustainable Sites		**Possible Points**	**Achieved Points**
Prereq 1	Construction Activity Pollution Prevention	Prerequisite	
Credit 1	Site Selection	1	1
Credit 2	Development Density and Community Connectivity	5	5
Credit 3	Brownfield Redevelopment	1	0
Credit 4.1	Alternative Transportation-Public Transportation Access	6	6
Credit 4.2	Alternative Transportation-Bicycle Storage and Changing Rooms	1	1
Credit 4.3	Alternative Transportation-Low-Emitting and Fuel-Efficient Vehicles	3	3
Credit 4.4	Alternative Transportation-Parking Capacity	2	2
Credit 5.1	Site Development-Protect or Restore Habitat	1	1
Credit 5.2	Site Development-Maximize Open Space	1	1
Credit 6.1	Stormwater Design-Quantity Control	1	1
Credit 6.2	Stormwater Design-Quality Control	1	0
Credit 7.1	Heat Island Effect-Non-roof	1	0
Credit 7.2	Heat Island Effect-Roof	1	0
Credit 8	Light Pollution Reduction	1	0
Water Efficiency			
Prereq 1	Water Use Reduction-20% Reduction	Prerequisite	
Credit 1	Water Efficient Landscaping	4	2
Credit 2	Innovative Wastewater Technologies	2	0
Credit 3	Water Use Reduction	4	3
Energy and Atmosphere			
Prereq 1	Fundamental Commissioning of Building Energy Systems	Prerequisite	
Prereq 2	Minimum Energy Performance	Prerequisite	

Table 4.29. LEED scorecard of Case 4 (cont.).

Sustainable Sites		**Possible Points**	**Achieved Points**
Prereq 3	Fundamental Refrigerant Management	Prerequisite	
Credit 1	Optimize Energy Performance	19	9
Credit 2	On-Site Renewable Energy	7	0
Credit 3	Enhanced Commissioning	2	0
Credit 4	Enhanced Refrigerant Management	2	2
Credit 5	Measurement and Verification	3	3
Credit 6	Green Power	2	0
Materials and Resources			
Prereq 1	Storage and Collection of Recyclables	Prerequisite	
Credit 1	Building Reuse-Maintain Existing Walls, Floors, and Roof	4	0
Credit 2	Construction Waste Management	2	0
Credit 3	Materials Reuse	1	0
Credit 4	Recycled Content	2	2
Credit 5	Regional Materials	2	2
Credit 6	Rapidly Renewable Materials	1	0
Credit 7	Certified Wood	1	0
Indoor Environmental Quality			
Prereq 1	Minimum Indoor Air Quality Performance	Prerequisite	
Prereq 2	Environmental Tobacco Smoke (ETS) Control	Prerequisite	
Credit 1	Outdoor Air Delivery Monitoring	1	1
Credit 2	Increased Ventilation	1	1
Credit 3.1	Construction Indoor Air Quality Management Plan-During Construction	1	1
Credit 3.2	Construction Indoor Air Quality Management Plan-Before Occupancy	1	1
Credit 4.1	Low-Emitting Materials-Adhesives and Sealants	1	0
Credit 4.2	Low-Emitting Materials-Paints and Coatings	1	0
Credit 4.3	Low-Emitting Materials-Flooring Systems	1	0
Credit 4.4	Low-Emitting Materials-Composite Wood and Agrifiber Products	1	0
Credit 5	Indoor Chemical and Pollutant Source Control	1	1
Credit 6.1	Controllability of Systems-Lighting Comfort	1	1
Credit 6.2	Controllability of Systems-Thermal Comfort	1	0
Credit 7.1	Thermal Comfort-Design	1	1
Credit 7.2	Thermal Comfort-Verification	1	1
Credit 8.1	Daylight and Views-Daylight	1	1
Credit 8.2	Daylight and Views-Views	1	1
Innovation and Design			
Credit 1	Innovation in Design: Specific Title	5	2
Credit 2	LEED Accredited Professional	1	1
Regional Priority			
Credit 1	Regional Priority: Specific Credit	4	3
Total Points		**110**	**60**

4.3.2.1. Sustainable Sites. Sustainable sites category deals with the issues related to site location, its relation with surroundings and how the open space is designed.

4.3.3. Prerequisite 1, Construction Activity Pollution Prevention

An Erosion and Sedimentation Control (ESC) Plan is created and implemented for all construction activities. The plan conformed to the erosion and sedimentation requirements of the U.S. 2003 EPA Construction General Permit (USGBC, 2009).

4.3.4. Credit 1, Site Selection

The intent of this credit is to avoid the development of inappropriate sites and reduce the environmental impact from the location of a building on a site. The site was used as a parking lot before and it complies with the credit. The credit is taken without any effort.

4.3.5. Credit 2, Development Density and Community Connectivity

A map of surroundings is prepared in order to show the building density in the community. Each number on the map presents a building block. The approximate floor and site area of each building block is documented. The map can be seen in Figure 4.54. The project complied without effort.

4.3.6. Credit 4.1, Alternative Transportation-Public Transportation Access

The project complied with this credit providing campus bus services to the main transportation hubs such as Gebze and Kocaeli. The refinery provides regular services that are free for all refinery employee and visitors.

Figure 4.54. Development density map of Case 4.

4.3.7. Credit 4.2, Alternative Transportation-Bicycle Storage and Changing Rooms

The bicycle racks are put on the open space and shower and changing facilities are deigned in the ground floor for the use of occupants. Implementation of these facilities resulted in additional costs. It is estimated that 180 people will work in the building. Thus, 24 secure bicycle racks and 2 shower facilities are provided.

4.3.8. Credit 4.3, Alternative Transportation - Low - Emitting and Fuel-Efficient Vehicles

The capacity of the carpark is 30. The closest 2 parking spots are reserved for green vehicles such as electrical or hybrid cars. Signage are put for these spaces as shown on the Figure 4.55.

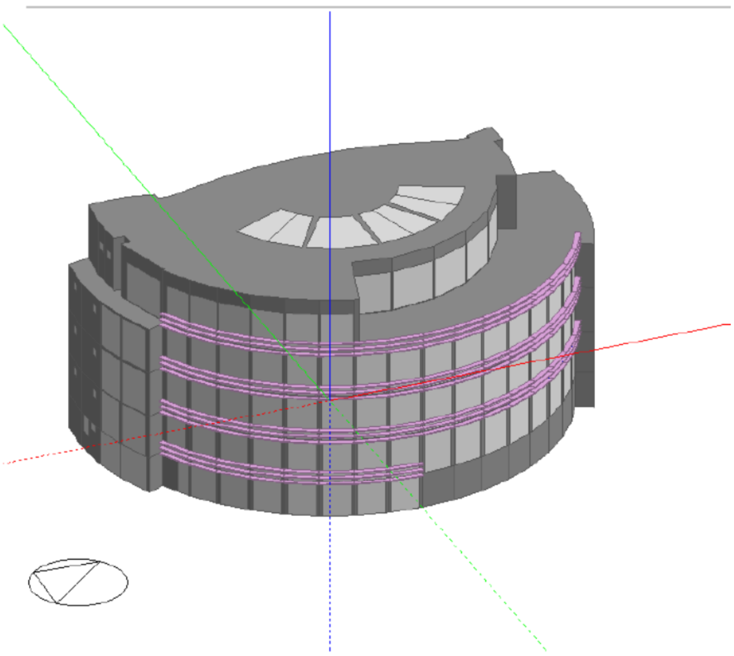

Figure 4.55. Green vehicle signage of Case 4.

4.3.9. Credit 4.4, Alternative Transportation - Parking Capacity

The number of provided car park cannot exceed the minimum number given in the local regulation (USGBC, 2009). The capacity of the carpark is 30 where the car parking regulation requires 87 (one car park for 50 m^2 of office space). The credit is achieved without additional costs but it was depended on the concept architectural project.

4.3.10. Credit 5.1, Site Development - Protect or Restore Habitat

The aim of this credit is to provide habitat and promote biodiversity by increasing native or adapted vegetated areas in the project. 20% of total site area (including building footprint) should be landscaped with vegetation as a rule (USGBC, 2009). The roof of the conference center is designed as green roof in order to contribute this credit. The project site is 4,200 m^2 and it is designed to have 1,500 m^2 of green landscape and 300 m^2 of vegetated roof which results 42% vegetated area. The plants are selected from native to the local climate or adapted species by the landscape designer. The green roof implementation resulted in additional costs.

4.3.11. Credit 5.2, Site Development - Maximize Open Space

The aim of this credit is to open space for the building users. 20% of total site area (including building footprint) should be landscaped or open to pedestrian access (USGBC, 2009). The project site has 2,000 m^2 of open space containing green and pedestrian area which is 44% of total site. The credit is achieved without additional costs but it was depended on the concept architectural project.

4.3.12. Credit 6.1, Stormwater Design - Quantity Control

A stormwater management plan is implemented that results in a 25% decrease in the volume of stormwater surface runoff from the two-year 24-hour design storm compared to previous condition of the site. The previous condition of the site had impervious cover (hardscape) of 90% of total site. After landscaping in the project the impervious cover on the site decreased to 50%. As a result, the water runoff to sewers are reduced approximately 30%. The credit is achieved without additional costs but it was depended on the concept architectural project. Additionally, cost for green roof is counted in the credit 5.1 Site Development-Protect or Restore Habitat.

4.3.12.1. Water Efficiency. This category evaluates the buildings domestic and landscaping water consumption.

4.3.13. Prerequisite 1 and Credit 3, Water Use Reduction

The project performed 35% better than the LEED baseline by selecting low consuming fixture equipment. The Table 4.29 shows the consumption values and selected equipment. The project complies with the prerequisite and credit 3 by choosing these water fixtures. These fixtures can be found in the Turkish market and there is not a significant cost premium.

Table 4.29. Water fixtures of Case 4.

Fixture Type	**Baseline Consumption Value (EPA, 2009)**	**Installed Consumption Value**	**Unit**	**Brand**	**Model**
Water Closets	6	4	liter/flush	VITRA	711-1850
Urinals	3.78	1	Liter/flush	VITRA	310-2111
Lavotaries	2	2	liter/cycle	VITRA	A47008WS
Shower Head	9.5	6	liter/min	VITRA	ISTANBUL A4801592

4.3.14. Credit 1, Water Efficient Landscaping

The landscape has an area of 1,800 m^2 and it contains mainly trees, shrubs and flowers. No turf grass is installed in the project which has the highest consumption value. Instead of turf grass, natural ground cover found in the region is implemented. The list of plants chosen in the project is shown in the Table 4.26. Automated drip irrigation system is implemented in the project instead of conventional sprinkler system. 60% reduction according to LEED baseline is achieved in irrigation consumption.

Table 4.30. Plants selected in Case 4.

Local Plant Name	**Latin Name**
Defne	Laurus nobilis
Porsuk	Taxus baccata
Lavanta	Lavandula officinalis
Ortanca	Hydrangea hortensis
Bodur zakkum	Nerium olender
Erika	Erica arborea /
Ihlamur	Tilia tomentosa
Mese	Quercus Ilex

4.3.14.1. Energy and Atmosphere. Energy and Atmosphere category includes credits about maximizing energy efficiency, renewable energy production, energy monitoring and depletion of ozone layer.

4.3.15. Prerequisite 1, Commissioning of Building Energy Systems

In this project, commissioning is performed by the Tupras Facility Management as a standard procedure. All process is reviewed by the commissioning team of Tupras. Energy management training and system manual are prepared for the personnel. This credit did not create additional costs.

4.3.16. Prerequisite 2 and Credit 1, Optimize Energy Performance

This is the most important credit of the LEED certification with a total available points of 19. The intent of the credit is to establish the level of energy efficiency for the proposed building and systems to reduce environmental and economic impacts associated with excessive energy use. The energy efficiency of the building is measured by doing building energy modeling (USGBC, 2009).

The energy modeling of the building is done using Designbuilder software by the consultant company. The 3D view from energy modeling software is shown on the Figure 4.56. According to energy modeling results, the building achieved 28% reduction compared to ASHRAE 90.1-2007 baseline building. Thus, the building earned 9 points out of 19 points in this credit.

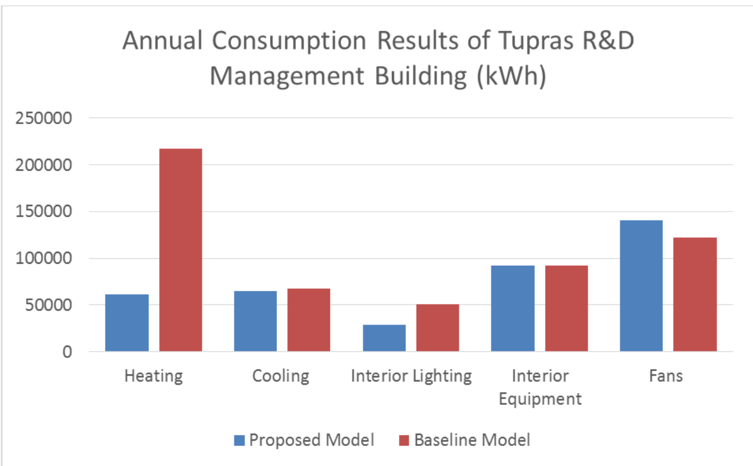

Figure 4.56. 3D view of energy model of Case 4.

Architecture of the building is modeled as it is designed. The architect could not change the design since the decision for LEED is taken after the design is completed. However, there are already energy efficiency measures present in the building. Sun shading devices on the south side of the building prevent excessive heating in summer months. Naturally ventilated atrium with operable skylights support the cooling system of the building. LED lighting is implemented to decrease energy consumption.

The HVAC system is modeled based on the mechanical drawings provided by the mechanical group. Mechanical equipment data represent the actual design conditions. The heating and cooling demand of the building is provided by VRV system which is coupled with 3 air handling units for fresh air supplement purpose to building zones. Air Handling Units are CAV plants with 35% fresh air rate. Additionally, single heat recovery units are used for basement floor and for the terrace floor café zone. Toilet zones are modeled only with exhaust fans. Natural ventilation is modelled especially for kitchen zones to decrease the overheating.

The project did not implement additional strategies to increase energy efficiency since the design was completed when it is decided to pursue LEED. Figure 4.57 shows the annual energy consumption results of different load types. Improvement is achieved in heating and interior lighting. There is no improvement in cooling, fans and equipment loads such as receptacle loads, elevators, exhaust fans.

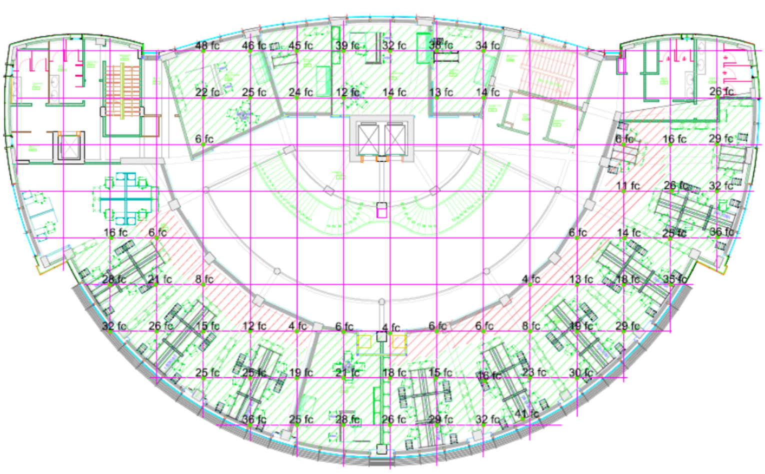

Figure 4.57. Detailed Modeling Results of Case 4.

4.3.17. Prerequisite 3 and Credit 4, Refrigerant Management

The type and amount of refrigerant gas of the installed systems are calculated in order to find ozone impact. In this project, R-410A type of refrigerant gas is used which complies with the credit requirement. There is not any additional costs for this credit.

4.3.18. Credit 5, Measurement and Verification

Metering equipment to measure energy use of cooling, heating and other electrical systems are installed which are connected to a central automation system which monitors and reports the consumption results regularly. Metering equipment and automation system was already planned in concept stage in this project. Thus, associated costs are resulted because of LEED certification.

4.3.18.1. Materials and Resources. Materials and resources category includes credits is mainly related to production construction materials and recycle opportunities.

4.3.19. Prerequisite 1, Storage and Collection of Recyclables

Recycle bins are for paper, glass, plastics and metals are located on the common areas next to elevators on every floor. Building management collects these bins every night and transfers to storage areas in the campus. Recyclable waste collection of the local municipality occurs twice a week. There are additional costs for the recycle bins.

4.3.20. Credit 4, Recycled Content

Construction materials should have recycled content for at least 20% based total on cost. Typically, new rebar used in reinforced concrete structure are produced from scrap iron collected from the region. It does have around 95% post-consumer content. Thus, for the reinforced concrete structures this credit is achieved without effort.

4.3.21. Credit 5, Regional Materials

The project selected materials that are harvested and manufactured within 800 km for at least 20% of all construction materials based on cost in order to comply with the credit. In this project, raw materials of concrete are manufactured within 800 km distance. Manufacturer letters and explanatory documents are used for LEED documentation. As a result, the credit is complied without costs.

4.3.21.1. Indoor Environmental Quality. This category includes measures related to indoor air quality and occupant comfort.

4.3.22. Prerequisite 1 and Credit 2, Ventilation

The projects shall provide 30% above the minimum rates required by ASHRAE 62-1 2007 standard (USGBC, 2009). The mechanical ventilation systems and air handling equipment of the project are designed according to this requirement from the early design. Thus, no additional costs are associated with the credit.

4.3.23. Prerequisite 2, Environmental Tobacco Smoke Control

In order to comply with this credit smoking is prohibited around the building within 8 meters of entrances. Smoking is already prohibited in Tupras refinery campus. Thus, this practice didn't create any additional costs.

4.3.24. Credit 1, Outdoor Air Delivery Monitoring

The project has placed direct airflow measurement devices on each air handling unit and connected to the central building automation system in order to comply with the credit. Additionally, CO_2 sensors are placed in densely occupied spaces. These units resulted in a cost increase for the project.

4.3.25. Credit 3, Construction Indoor Air Quality Management Plan

An indoor air quality management plan for construction phase is developed and implemented. The plan includes measures such as protection of ductwork and air handling equipment from dust, local temporary exhaust during dust creating indoor construction activities, controlling pollution of indoor spaces, protection of sensitive materials, preventing odor and other air contaminants during construction, storing of chemicals in a separate and closed area (USGBC, 2009). These practices do not require additional costs but a good management and regular monitoring.

4.3.26. Credit 5, Indoor Chemical and Pollutant Source Control

The purpose of this credit is to reduce the entry of pollutants into the building and expose of contaminants inside the building. Self-closing hydraulic doors are installed in spaces where hazardous gases are present. 3-meter-long entryway mats are placed on every entrance of the building. The implementation is resulted in a cost increase.

4.3.27. Credit 6.1, Controllability Systems-Lighting

This credit aims to provide lighting control for each individual work station to increase comfort. Desk lamps are added on every work station in order to comply with this credit. The implementation resulted in a cost increase.

4.3.28. Credit 7, Thermal Comfort - Design and Verification

The mechanical design team provided documentation that shows the compliance with the ASHRAE 55-2004 thermal comfort standard via the online CBE (Center for Built Environment) Thermal Comfort Tool. A survey is conducted between building occupants in order to assess the comfort levels of the building. The implementation has negligible costs.

Figure 4.58. Daylight measurement plan of Case 4.

4.3.29. Credit 8.1, Daylight and Views - Daylight

Daylight level measurements are made in order to prove the compliance with the LEED requirement of daylight levels. More than 75% of all regularly occupied spaces such as offices and retail areas achieve daylight illuminance levels of a minimum of 110 lux in a clear sky condition. The architectural design of the building was already compliant with the credit with large windows and skylight as shown in Figure 4.58. Thus, no additional changes or costs are applicable for the credit. The measurements are done by the LEED consultant as part of their scope. A sample measurement plan is given in Figure 4.57. Green hatched area has sufficient daylight levels.

4.3.30. Credit 8.2, Daylight and Views - Views

90% of all regularly occupied areas should have outside views for this credit compliance (USGBC, 2009). The compliance is shown via the building floor plans and sections. This credit didn't require any changes in the existing architectural design.

4.3.31. Credit 1, Innovation in Design

Exceptional performance is achieved in three credits where the required LEED threshold is doubled by the project. These are Sustainable Sites Credit 5 Maximize Open Space and Materials and Resources Credit 5 Regional Materials. These performance credits are achieved without an effort (USGBC, 2009).

4.3.32. Credit 2, LEED Accredited Professional

In order to achieve this credit at least one principal participant of the project team shall be a LEED Accredited Professional (USGBC, 2009). The project worked with a LEED consultancy company which has an assigned LEED AP for the project. LEED AP is included in the project from the early design to completion. LEED consultancy fees are included in the project as soft cost.

4.3.33. Credit 1, Regional Priority

This credit aims projects to provide an incentive for the achievement of credits that address geographically-specific environmental priorities. This project earned three of four credits without an effort (USGBC, 2009).

4.3.33.1. Impact on Project Budget. In the previous chapter the green building implementation of each credit is explained and it is stated if they create additional costs or not. In this chapter, the additional costs are explained. The associated costs for each credit are investigated during the research with interviews and examinations of documents.

In this study, the costs are categorized in two ways. Firstly, the costs are categorized as hard and soft costs. Hard costs are resulted from purchases of additional or more expensive materials and equipment, physical implementation of green building strategies and associated labor costs. Soft costs include LEED consultancy fees, energy modeling fees, LEED certification fees and costs related to additional paperwork.

Secondly, it is found out that the costs can be classified in four categories: 1) Low size-sensitive costs 2) High size-sensitive costs 3) Costs depending the concept design 4) Negligible cost. Low size-sensitive costs are costs that have a minimum value and do not change significantly with the project size. These can also be considered as fixed costs. High size sensitive costs mainly depend on the project size and they can be considered as fixed costs per area. These costs can vary from zero to high values. Costs depending concept design are mostly depended on the project decisions and conditions. Some projects can comply with credits without any cost or any effort where some projects may result in high cost increase. Lastly, no cost credits are credits that can be achieved in almost all projects without cost increase independent from design. Credits that created additional costs are explained below:

4.3.34. Sustainable Sites Credit 4.2, Alternative

Transportation-Bicycle Storage and Changing Rooms In order to comply with the credit 24 bicycle racks, 2 showers and changing rooms are added into the project. Estimate cost for the bicycle racks are \$1200 (\$50 x 24). Estimated cost for shower and changing rooms are \$2000 (\$2000 x 4). Total cost of this credit is \$3200. This is a high size-sensitive cost hard cost since it the required number of units increase with the building size.

4.3.35. Sustainable Sites Credit 5.1, Site Development - Protect or Restore Habitat

In order to comply with Sustainable Sites credits about green area, rainwater management and heat island effect additional vegetated area are implemented on the site and on the roof. This implementation resulted in a hard cost increase highly sensitive with project size. 250 m^2 green roof and 1600 m^2 green area created a total cost increase of \$31,500.

4.3.36. Energy and Atmosphere Prerequisite 2, Energy Performance

The costs related to the energy performance is not easy to evaluate since there are many factors affecting the performance of a building such as orientation, architecture, envelope properties, mechanical and lighting systems. Some buildings may need huge changes and a lot of effort to achieve this credit and some buildings may achieve the credit without effort. It is mostly related on the concept design.

In this project, the project team stated that there aren't any changes made in the design for the LEED purpose. The existing design of the project was capable to earn points. Thus, there aren't any hard costs related to energy efficiency. A consultancy company specialized in energy simulation is hired for the energy simulation work of the project. The fee of the company is $10,000. This fee is considered as a soft cost.

4.3.37. Materials and Resources Prerequisite 1, Storage and Collection of Recyclables

For the purpose of this credit four recycle bins are provided on every floor. The cost of the bins is $2000 (20 bins x $100). This item is categorized as high size-sensitive hard cost.

4.3.38. Indoor Environmental Quality Credit 1, Outdoor Air Delivery Monitoring

In order to comply with the credit outdoor air flow measurement devices are added on every air handling unit in the building. The devices are connected with the building automation system which was already included in the project. Cost of the air flow measurement devices is $750 (3 units x $250). CO2 sensors are placed in every densely occupied zones including open office, restaurant, conference center, meeting rooms. There 18 CO2 sensors which show the CO2 levels to the building occupants. The cost of these sensors is $7200 ($400 x 18). This item is categorized as high size-sensitive hard cost.

4.3.39. Credit 5, Indoor Chemical and Pollutant Source Control

2 Self-closing hydraulic doors are installed in spaces where hazardous gases are present which resulted in a cost increase of $3,000 (2 x $1,500). 2 3-meter-long entryway mats are placed on every entrance of the building which resulted in a cost increase of $800 (2 x $400). The implementation is resulted in a hard cost increase highly sensitive to project size.

4.3.40. Credit 6.1, Controllability Systems-Lighting

Desk lamps are added on every work station in order to comply with this credit. 162 lamps are bought for this purpose. The resulted cost increase is $6480 (162 x $40). The implementation is resulted in a hard cost increase highly sensitive to project size.

4.3.41. LEED Consultancy Fees

The project hired a LEED consultancy company for the whole certification process. The company was available from the beginning of the design until the occupancy and managed the LEED certification. The services the LEED consultancy company provided includes; preparation of LEED documentation and sustainability charrette, establishing project goals and assigning roles, technical consultancy for project teams about sustainability practices and energy efficiency, supervision of construction activities, documentation and achievement of certification, support for green marketing. The fee of the company is $20,000. This item is categorized as low size-sensitive cost and soft cost.

4.3.42. LEED Certification Fees

Green Building Certification Institute (GBCI) is the only authorized institution by U.S. Green Building Council that provides LEED certification in the world. The institute reviews documentation provided by LEED consultants via an online system and awards the certification accordingly. LEED certification fees which include registration fee, design review fee and construction review fee are paid to the GBCI. The fees are calculated according to building floor area. A discount is applicable for US-GBC premium members. The fees can be seen in Table 4.30. The sum of fees this project is \$4,000. This item is categorized as high size-sensitive soft cost.

Overall, a green building cost increase of \$88,930 which is 1.6% of total budget and \$19.7/m^2 is estimated. All credits and related costs are summarized in table 4.27. On the table, costliest items are energy performance, LEED consultancy services and vegetated area implementation.

Table 4.32. LEED Costs of Case 4.

Credit Number/Name		Cost Type 1	Cost Type 2	Implemented Cost Items	Costs (USD)
Prereq 1	Construction Activity Pollution Prevention	Hard Cost	High Size-sensitive costs	Requirements mentioned in contractor's specifications. No additional costs created due low size.	0
Credit 1	Site Selection	No cost	No cost	The site meets requirements. No costs are involved.	0
Credit 2	Development Density and Community Connectivity	No cost	No cost	The site meets requirements. No costs are involved.	0
Credit 4.1	Alternative Transportation-Public Transportation Access	No cost	No cost	The site meets requirements. No costs are involved.	0
Credit 4.2	Alternative Transportation-Bicycle Storage and Changing Rooms	Hard Cost	High Size-sensitive costs	24 bicycle racks and construction of 2 shower and changing rooms	3200
Credit 4.3	Alternative Transportation-Low-Emitting and Fuel-Efficient Vehicles	Hard Cost	High Size-sensitive costs	No significant cost because of low size	0
Credit 4.4	Alternative Transportation-Parking Capacity	Hard Cost	High Size-sensitive costs	No significant cost because of low size	0
Credit 5.1	Site Development-Protect and Restore Habitat	Hard Cost	Costs depending concept design	250 m^2 Green roof and 1,600 m^2 vegetated area implementation	31500
Credit 5.2	Site Development-Maximize Open Space	Hard Cost	Costs depending concept design	The cost is given in above credit 5.1	0

Table 4.32. LEED Costs of Case 4 (cont.).

Credit Number/Name		**Cost Type 1**	**Cost Type 2**	**Implemented Cost Items**	**Costs (USD)**
Credit 6.1	Stormwater Design-Quantity Control	Hard Cost	Costs depending concept design	The cost is given in above credit 5.1	0
Credit 7.1	Heat Island Effect-Non-roof	Hard Cost	Costs depending concept design	Project complies with negligible effort.	0
Credit 7.2	Heat Island Effect-Roof	Hard Cost	Costs depending concept design	The cost is given in above credit 5.1	0
Water Efficiency					
Prereq 1	Water Use Reduction-20% Reduction	Hard Cost	Costs depending concept design	Water efficiency is provided by selecting low consuming fixtures. These do not create significant cost increase in the market.	0
Credit 1	Water Efficient Landscaping	Hard Cost	Costs depending concept design	Water efficient landscaping is provided by selection low consuming plants.	0
Credit 2	Innovative Wastewater Technologies	Hard Cost	Costs depending concept design	Water efficiency is provided by selecting low consuming fixtures.	0
Credit 3	Water Use Reduction	Hard Cost	Costs depending concept design	Water efficiency is provided by selecting low consuming fixtures.	0

Table 4.32. LEED Costs of Case 4 (cont.).

Credit Number/Name		**Cost Type 1**	**Cost Type 2**	**Implemented Cost Items**	**Costs (USD)**
Energy and Atmosphere					
Prereq 1	Fundamental Commissioning of Building Energy Systems	Soft Cost	Low size-sensitive Costs	Commissioning is conducted by Tupras team.	0
Prereq 2	Minimum Energy Performance	Soft	Costs depending concept design	Energy modeling consultancy service	10000
Prereq 3	Fundamental Refrigerant Management	No cost	No cost	Project complies with negligible effort.	0
Credit 1	Optimize Energy Performance	Soft and Hard Cost	Costs depending concept design	Cost is given in EAp2	0
Credit 4	Enhanced Refrigerant Management	Hard Cost	No cost	Project complies with negligible effort.	0
Credit 5	Measurement and Verification	Hard Cost	Costs depending concept design	Project complies with negligible effort.	0
Materials and Resources					
Prereq 1	Storage and Collection of Recyclables	Hard Cost	High size-sensitive costs	20 recycle bins are put	2000
Credit 4	Recycled Content	No cost	No cost	Project complies with negligible effort.	0
Credit 5	Regional Materials	No cost	No cost	Project complies with negligible effort.	0

Table 4.32. LEED Costs of Case 4 (cont.).

Credit Number/Name		**Cost Type 1**	**Cost Type 2**	**Implemented Cost Items**	**Costs (USD)**
Indoor Environmental Quality					
Prereq 1	Minimum Indoor Air Quality Performance	No cost	No cost	Project complies the credit without cost.	0
Prereq 2	Environmental Tobacco Smoke (ETS) Control	No cost	No cost	No costs	0
Credit 1	Outdoor Air Delivery Monitoring	Hard Cost	High size-sensitive costs	Addition of 3 outdoor air flow measurement and 18 CO2 sensors	7950
Credit 2	Increased Ventilation	No cost	No cost	Project complies with negligible effort.	0
Credit 3.1	Construction Indoor Air Quality Management Plan-During Construction	No cost	No cost	The requirements are added into the contractor's specifications. Related costs are unknown but it is assumed negligible	0
Credit 3.2	Construction Indoor Air Quality Management Plan-Before Occupancy	No cost	No cost	The requirements are added into the contractor's specifications. Related costs are unknown but it is assumed negligible	0
Credit 5	Indoor Chemical and Pollutant Source Control	Hard Cost	High size-sensitive costs	Additional 2 entry mats and 2 hydraulic doors.	3800
Credit 6.1	Controllability of Systems - Lighting	Hard Cost	Costs depending concept design	Additional desk lighting for 162 workstations	6480
Credit 7.1	Thermal Comfort-Design	No cost	No cost	Project complies with negligible effort.	0
Credit 7.2	Thermal Comfort-Verification	Hard Cost	Costs depending concept design	Project complies with negligible effort.	0
Credit 8.2	Daylight and Views-Views	Hard Cost	Costs depending concept design	Project complies with negligible effort.	0

Table 4.32. LEED Costs of Case 4 (cont.).

Credit Number/Name		**Cost Type 1**	**Cost Type 2**	**Implemented Cost Items**	**Costs (USD)**
Innovation and Design					
Credit 1	Innovation in Design: Specific Title	No cost	No cost	Project complies with negligible effort.	0
Credit 2	LEED Accredited Professional	Soft Cost	Low size-sensitive costs	Included in LEED consultancy fees	0
Regional Priority					
Credit 1	Regional Priority: Specific Credit	No cost	No cost	Project complies with negligible effort.	0
LEED Certification Fees		Soft Cost	High size-sensitive costs	Calculated by floor area	4000
Consultancy Fees		Soft Cost	Low size-sensitive costs	LEED consultancy service costs	20000
Total cost (USD)					**88930**

5. DISCUSSION

The green building implementation and related costs are investigated in the Case studies. Conclusions are drawn according to findings and discussions are provided in the next chapter.

5.1. Green Building Implementation

The green building implementation investigated in the Case studies are based on the LEED certification since it is the most common certification and benchmark system for green building. LEED certification contains certain criteria to be implemented as prerequisites and credits. Although projects can choose which credit to pursue, it is seen that the criteria that Case studies implemented are generally in common. These common practices implemented by the buildings are listed below:

- Smart site selection: close to public transport and in dense urban area,
- Bicycle racks and showers for building occupants,
- Preferred parking reserved for green cars,
- More green area on the ground and roofs,
- Light colored high reflective materials on the roofs,
- Low flow faucets, showers and low capacity reservoirs and urinals,
- Local and adaptive plants that consume less water and drip irrigation,
- Efficient mechanical cooling, heating and ventilating systems,
- Better building envelope insulation rates,
- LED lamps,
- Architectural sun shading devices,
- Third party commissioning service,
- Ability to measure energy consumption of different systems,
- Recycling of construction waste,
- FSC certified wood purchase,
- Outdoor air flow measurement devices on the air handling units,

- Carbon dioxide detectors in densely occupied spaces,
- Protection of indoor air quality during construction,
- Adhesives, paints and flooring products with low VOC content,
- Entryway mats in the building entrances,
- Maximum use of daylight and external views.

Some LEED credits can be fulfilled in different ways and strategies. Thus, although most of the practices to achieve a LEED Platinum certified building are common, there are some differences in the project's approach to fulfill the criteria. Practices that are implemented by only one of the Case studies are listed below:

- Grey water and rainwater collection and re-use,
- Solar panels on the roof for electricity production and water heating,
- Underground air labyrinth for increased cooling and heating efficiency,
- Slab cooling and heating system,
- Mesh building façade design.

5.2. Factors of Affecting Project Budget

It is found out, that even though most of the green building practices are in common in the Case studies, each practice had different impacts on project budget. Each individual project has special factors which may hinder or ease its process during green building certification process. These factors are: site selection, contractor's specifications, timing of green building decision and approach to the criteria.

Some of the credits are purely depended on site selection which shows the importance of timing for green building decision. The credits that are depended on site selection are worth of 12 points out of 110 total points. All Cases fulfilled the site selection criteria and achieved 12 points without any significant effort. These credits are not achieved to establish a green building. The motivation to achieve these credits are primary to increase the value of the property. Because of this fact, they are considered as no cost credits. These credits are listed below:

- Sustainable Site Credit 1: Site Selection (1 point),
- Sustainable Site Credit 2: Development Density (5 point),
- Sustainable Site Credit 4.1: Alternative Transportation-Public Transportation (6 point).

Some credits depend on the preparation of contractor's specifications. All Cases show that when the green building measures implemented during construction are put in the contractor's specifications no cost increase is reflected to the developer. For example, Materials and Resources Credit 2: Construction Waste Management requires the separation of recyclable waste during construction. This is achieved with almost no cost but with proper management of construction site. These credits can have a size-depending effect or negligible effect to the project budget. These credits are worth of 12 points and listed below:

- Materials and Resources Credit 2: Construction Waste Management (2 point),
- Materials and Resources Credit 4: Recycled Content (2 point),
- Materials and Resources Credit 5: Regional Materials (2 point),
- Indoor Environmental Quality Credit 3: Construction Indoor Air Quality Management (2 point),
- Indoor Environmental Quality Credit 4: Low Emitting Materials (4 point).

It is found out that most of the costs are depended on the timing of green building decision and project teams approach to the LEED credits. Most credits can be met with negligible cost increase if they are decided in earlier phases of the project and the design and construction is managed accordingly. In Case of a late decision for green building they may result in cost increase or implementation problems. Sometimes credits can result in high costs even though the project decided to go green in an early phase depending the project's team approach and projects circumstances. Therefore, the effects of these credits to the project budget are considered as costs depending concept design. For example, Sustainable Sites Credit 5.2 Maximize Open Space credit is achieved without additional costs in Case 2 because the landscape design fulfilled the requirements without any change. However, Case 1 implemented additional green area for the credit which resulted in a cost increase. Another example is Energy and Atmosphere Credit 1 Optimize Energy Performance. Design of the Case 1 was complied with the credit so that cost increase is minimum. Efficient mechanical system, LED lighting, external shading devices which are common applications in the market were present in the concept project. On the other hand, Case 2 implemented innovative strategies which required major design changes and high costs such as underground labyrinth, slab cooling and photovoltaic panels. Case 1 and Case 2 received the same score in the credit although the approaches are very different. These types of credits form most of the LEED and green building criteria and they are worth of approximately 80 points of 110 points.

5.3. Project Budget Impact Summary

The sum of green building implementation costs for LEED Platinum certified projects are found out as \$256,250 (\$3,4/m^2 and 0.43%) for Case 1, \$277,950 (\$55/m^2 and 3.97%) for Case 2. The cost increase in LEED Gold certified projects are found out as \$50,900 (\$5.6/m^2 and 0.72%) for Case 3 and \$88,93 (\$19.7/m^2 and 1.6%) for Case 4.

Figure 5.1 shows the comparison of total cost increases. It is seen that LEED Platinum certified projects have larger cost increases compared to LEED Gold certified projects as expected. Total cost increase for Platinum certified projects are between \$250,000 - \$300,000 where Gold certified project cost increase is between \$50,000 - \$100,000. Case 2 has more cost increase than Case 1 even though it is a much smaller building. Also, Case 4 has larger cost increase even it is smaller than Case 3.

On the Figure 5.2 cost increase percentages are given. They vary from 0.4% to 5%. Even though Case 1 is Platinum certified, the cost increase percentage is smaller than other Cases. Case 3 has also low cost increase. There may be several reasons for this result. Firstly, Case 1 and Case 3 are core and shell projects. Tenant area which is the large part of the building is left unfinished and not evaluated by LEED certification. Thus, the green building implementation is less costly to achieve. Secondly, owners of

Case 1 and Case 3 are both professional real estate developing companies which aim the most cost-effective way to achieve LEED certification mainly for marketing purposes. On the other hand, the owner of Case 2 is a non-profit organization and Case 4 is located in the largest oil refinery in Turkey. Both of them occupy and actively use the buildings by their selves. Thus, the green building strategies they implement in the buildings are not only meant for LEED certification.

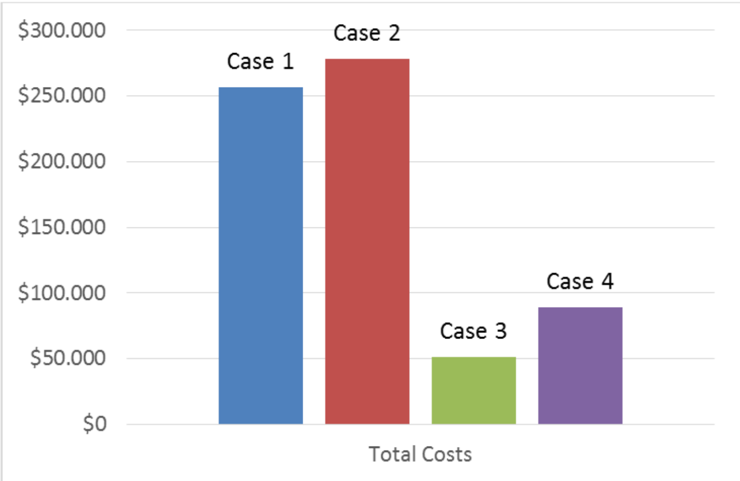

Figure 5.1. Total cost impact of examined Cases.

Table 5.1. Total cost impact of examined Cases.

Case 1	Case 2	Case 3	Case 4
$256.250	$277.950	$50.900	$88.930

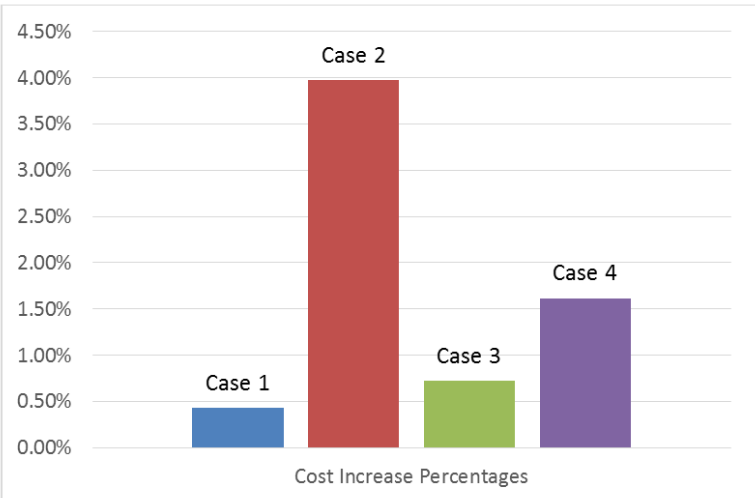

Figure 5.2. Cost increase percentages.

Table 5.2. Cost increase percentages.

Case 1	Case 2	Case 3	Case 4
0.43%	3.97%	0.73%	1.62%

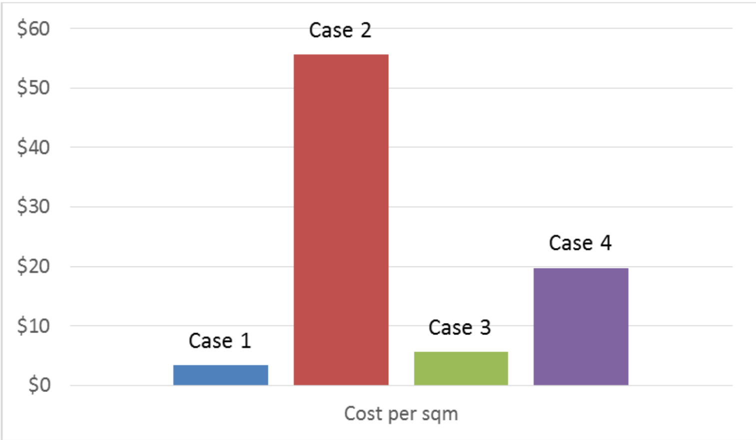

Figure 5.3. Cost increase per area (sqm.).

Table 5.3. Cost increase per area (sqm.).

Case 1	Case 2	Case 3	Case 4
$\$3.42/m^2$	$\$55,59/m^2$	$\$5,66/m^2$	$\$19,76/m^2$

The costs are categorized in two ways in this study. According to literature research costs related to LEED certification costs are mostly divided as soft and hard costs. Thus, in this study costs are firstly divided as hard and soft costs.

- Hard costs are costs related to material purchase, physical implementation of strategies and associated labor costs.
- Soft costs include costs of paperwork, certification fees, LEED related consultancy fees.

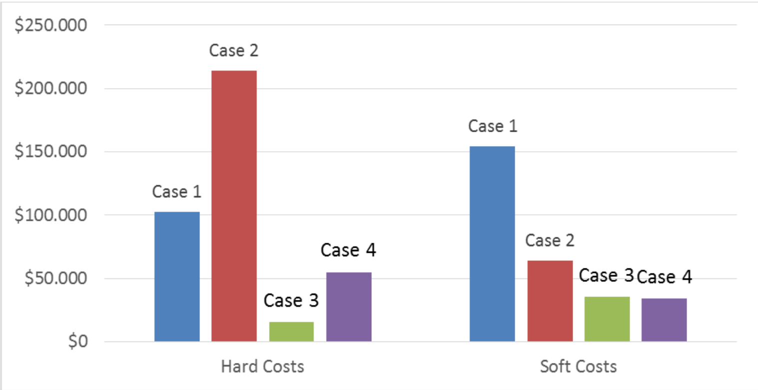

Figure 5.4. Sum of soft and hard costs.

Table 5.4. Sum of soft and hard costs.

	Case 1	Case 2	Case 3	Case 4
Hard Costs	$102.250	$213.950	$15.700	$54.930
Soft Costs	$154.000	$64.000	$35.200	$34.000

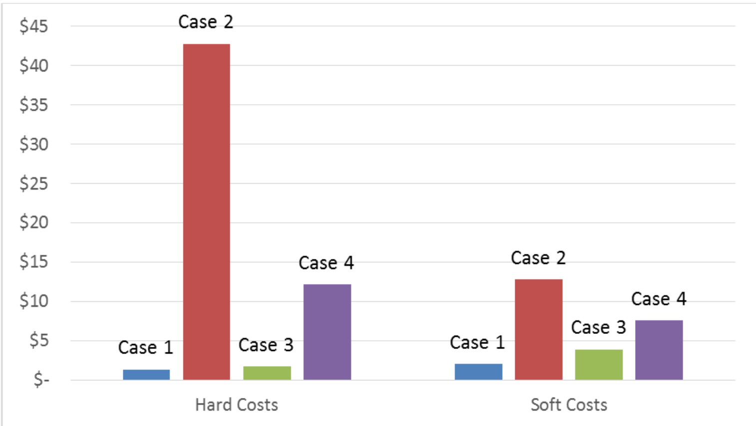

Figure 5.5. Soft and hard costs per sqm.

Table 5.5. Soft and hard costs per sqm.

	Case 1	Case 2	Case 3	Case 4
Hard Costs ($\$/m^2$)	1.36	42.79	1.74	12.21
Soft Costs ($\$/m^2$)	2.05	12.8	3.91	7.56

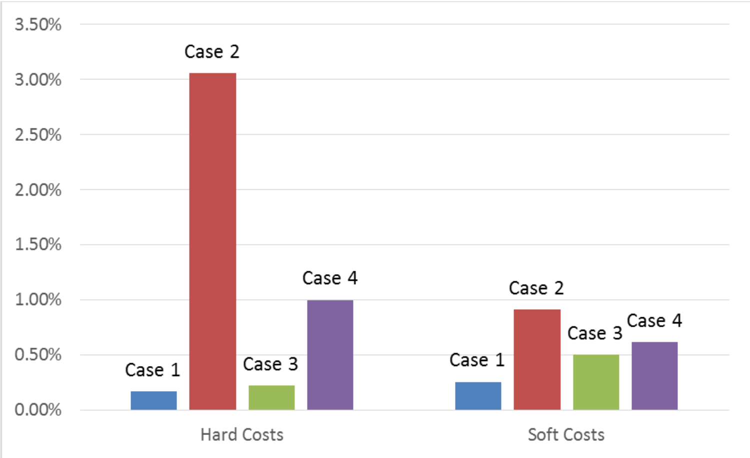

Figure 5.6. Percentage of soft and hard costs.

Table 5.6. Percentage of soft and hard costs.

	Case 1	**Case 2**	**Case 3**	**Case 4**
Hard Costs	0.17%	3.06%	0.22%	1.00%
Soft Costs	0.26%	0.91%	0.50%	0.62%

Figure 5.3 shows the cost distribution between soft and hard costs. On the figure, it can be seen that Case 2 has highest hard costs since the project included high cost strategies such as underground labyrinth, renewable energy production and slab cooling system. On the other hand, Case 1 is a core and shell project which does not include costs associated to interiors and developer's design standards already included energy efficiency measures which provided the project LEED points without costs. Because of these reason, there is a huge difference in hard costs between Case 1 and Case 2 even though they are both LEED Platinum certified. LEED Gold certified Case 3 and Case 4 have some differences in hard costs, too. Hard costs of Case 4 is larger than Case 3 even though Case 4 is a smaller building. The reason for that can be that Case 3 is a core and shell building and it does not have costs associated interiors. In terms of soft costs, Case 1 has highest soft costs. Case 1 included two buildings and much larger construction area. Thus, the soft costs such as LEED certification fees, consultancy fees, energy modeling fees are higher than Case 2. LEED Gold certified Case 3 and Case 4 has similar soft costs since the certification and consultancy fees are similar.

The costs are also divide into four categories in order to explain the impact in detail:

- Low size-sensitive costs, are costs that have a minimum value and do not change significantly with the project size. These can also be considered as fixed costs.
- High size sensitive costs mainly depend on the project size and they can be considered as fixed costs per area.
- Costs depending concept design are mostly depended on the project decisions and conditions. Some projects can comply with credits without any cost or any effort where some projects may result in high cost increase.
- No cost credits are credits that can be achieved in almost all projects without cost increase independent from design.

Figure 5.7 shows the cost distribution between low size-sensitive, high size-sensitive and concept design depending costs. On the figure, it is seen that low size-sensitive costs which are generally soft costs are similar between the same level certified projects. Case 1 included two buildings, thus the low-size sensitive costs of Case 1 is higher. Case 1 had higher cost increase in size sensitive costs as expected because Case 1 is the largest project between them. Case 2 has drastically higher cost increase in concept design related credits such as energy performance, water efficiency and landscaping.

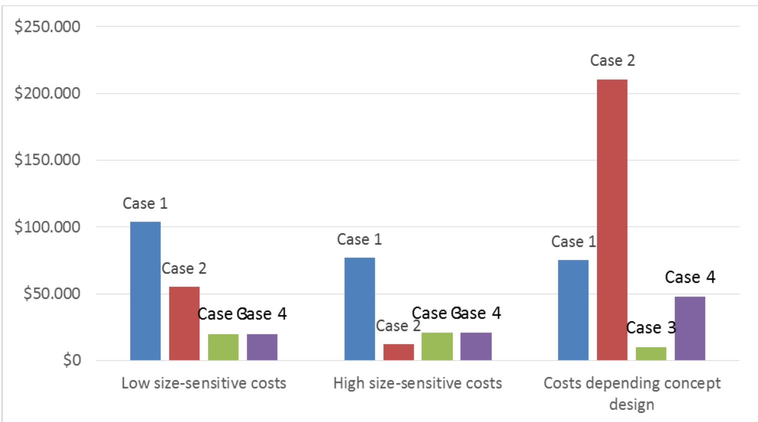

Figure 5.7. Total costs of cost categories.

Table 5.7. Total costs of cost categories.

	Case 1	**Case 2**	**Case 3**	**Case 4**
Sustainable Sites	\$104.000	\$55.000	\$20.000	\$20.000
Water Efficiency	\$76.750	\$12.300	\$20.900	\$20.950
Energy and Atmosphere	\$75.500	\$210.650	\$10.000	\$47.980

Figure 5.8 shows the costs per area (\$/m^2) and Figure 5.9 shows the cost increase percentage of cost categories. Case 2 and Case 4 have significantly more cost increase than other projects.

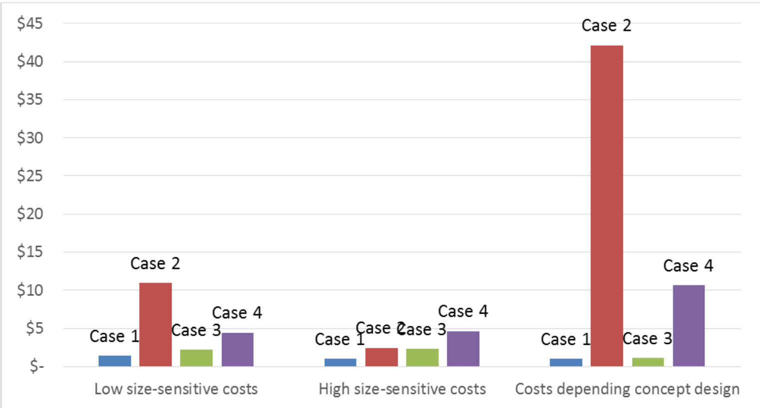

Figure 5.8. Costs per area (\$/m^2) of cost categories.

Table 5.8. Costs per area (\$/m^2) of cost categories.

	Case 1	**Case 2**	**Case 3**	**Case 4**
Sustainable Sites	1.39	11	2.22	4.44
Water Efficiency	1.02	2.46	2.32	4.66
Energy and Atmosphere	1.01	42.13	1.11	10.66

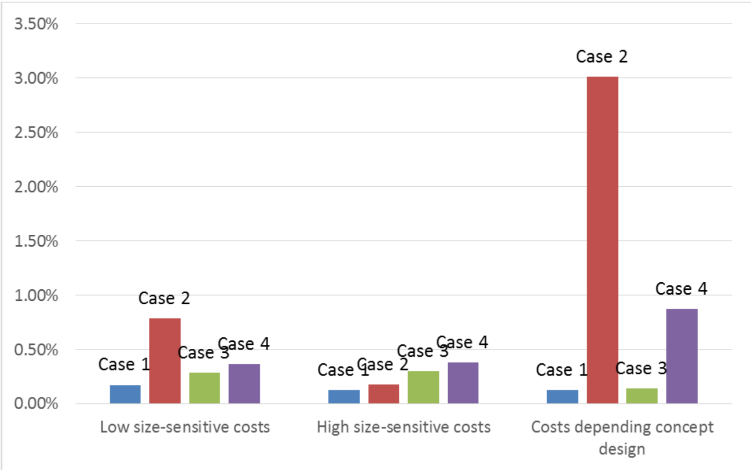

Figure 5.9. Cost increase percentage of cost categories.

Table 5.9. Cost increase percentage of cost categories.

	Case 1	**Case 2**	**Case 3**	**Case 4**
Sustainable Sites	0.17%	0.79%	0.29%	0.36%
Water Efficiency	0.13%	0.18%	0.30%	0.38%
Energy and Atmosphere	0.13%	3.01%	0.14%	0.87%

Figure 5.10 shows the total costs of LEED categories in the Cases. As seen on the figure, Water Efficiency, Materials and Resources and Indoor Environmental Quality categories have minimum impact on the project budget. Sustainable Sites category and Additional Costs (Consultancy and certification fees) create a cost increase proportional with the project size since Case 1 has significantly more costs in these categories. Energy and Atmosphere categories have cost impact depending the project teams approach without consideration of project size. Even though Case 2 has a smaller size, it had a large cost increase because of the team's decision to pursue energy efficiency in an innovative way.

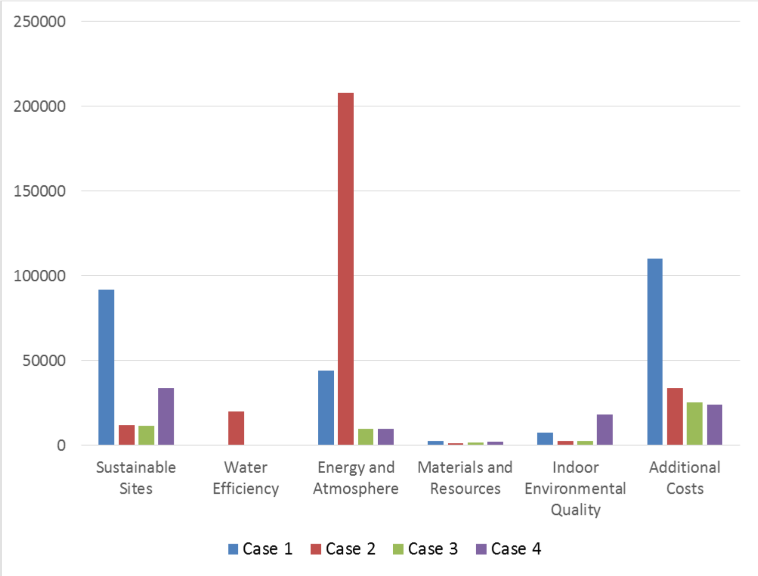

Figure 5.10. Total Costs of LEED Categories.

Table 5.10. Total Costs of LEED Categories.

	Case 1	**Case 2**	**Case 3**	**Case 4**
Sustainable Sites	\$91.950	\$11.800	\$11.600	\$33.700
Water Efficiency	0	20000	0	0
Energy and Atmosphere	\$44.000	\$208.000	\$10.000	\$10.000
Materials and Resources	\$2.800	\$1.500	\$1.600	\$2.000
Indoor Environmental Quality	\$7.500	\$2.650	\$2.500	\$18.230
Additional Costs	\$110.000	\$34.000	\$25.200	\$24.000

Figure 5.11 shows the costs per area (\$/m^2) and Figure 5.12 shows cost increase percentage of LEED categories. Both figures show that Case 2 invested in energy performance and water efficiency much more than Case 1 for Platinum level certification. Case 3, as a LEED Gold certified core and shell has the most costs in additional costs category including the certification and consultancy fees.

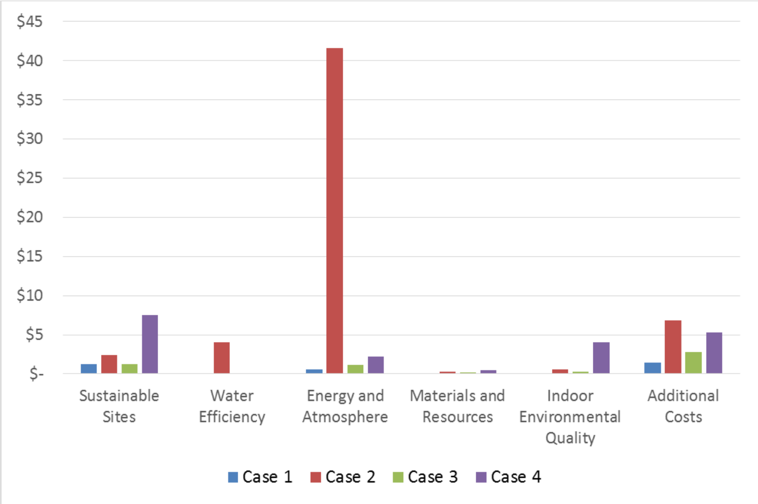

Figure 5.11. Cost per area ($\$/m^2$) of LEED Categories.

Table 5.11. Cost per area ($\$/m^2$) of LEED Categories.

	Case 1	**Case 2**	**Case 3**	**Case 4**
Sustainable Sites	1.23	2.36	1.29	7.49
Water Efficiency	0	4	0	0
Energy and Atmosphere	0.59	41.6	1.11	2.22
Materials and Resources	0.04	0.3	0.18	0.44
Indoor Environmental Quality	0.1	0.53	0.28	4.05
Additional Costs	1.47	6.8	2.8	5.33

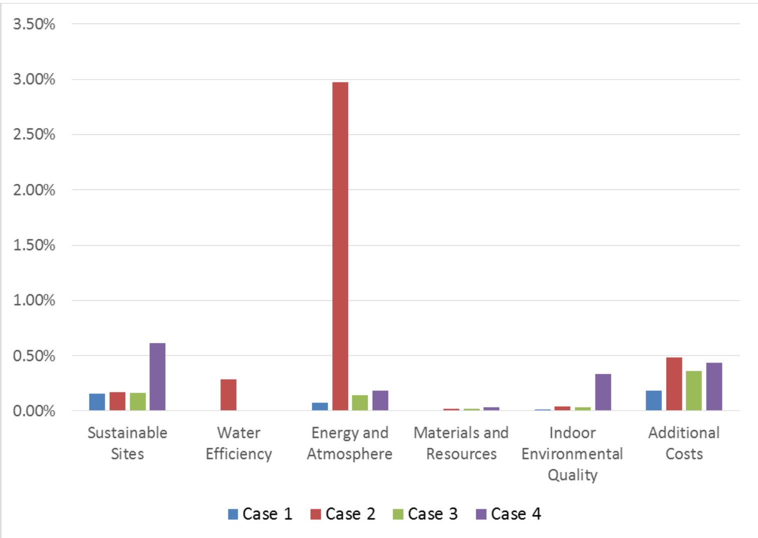

Figure 5.12. Cost increase percentage of LEED Categories.

Table 5.12. . Cost increase percentage of LEED Categories.

	Case 1	**Case 2**	**Case 3**	**Case 4**
Sustainable Sites	0.15%	0.17%	0.17%	0.61%
Water Efficiency	0.00%	0.29%	0.00%	0.00
Energy and Atmosphere	0.07%	2.97%	0.14%	0.18%
Materials and Resources	0.00%	0.02%	0.02%	0.04%
Indoor Environmental Quality	0.01%	0.04%	0.04%	0.33%
Additional Costs	0.18%	0.49%	0.36%	0.44%

On the Figure 5.13, items that have highest costs are shown for two Cases. Costliest items are minimum energy performance, LEED consultancy fees, site development, enhanced commissioning, LEED certification fees and bicycle storage and changing rooms. Case 2 had higher costs in energy efficiency which relates mainly to concept design and Case 1 had higher costs which are size-sensitive such as site development, bicycle storage and showers, certification and consultancy fees since Case 1 is the largest project. Case 3 and 4 has similar costs in these credits except the site development credit.

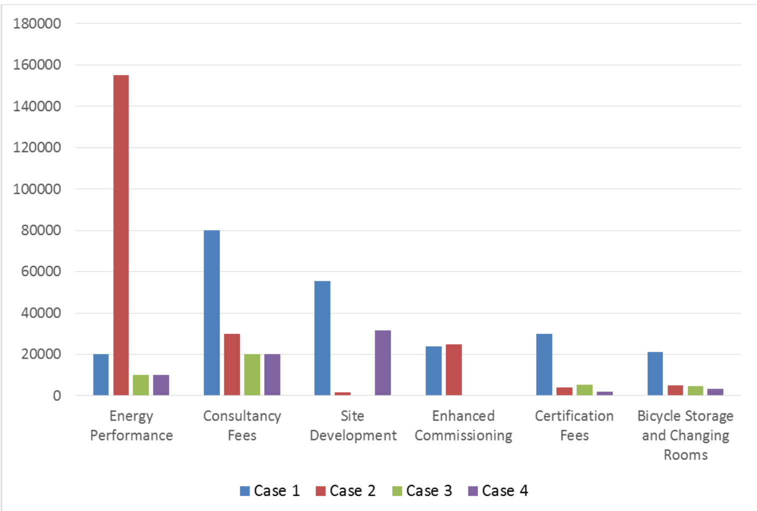

Figure 5.13. Total costs of costliest credits.

Table 5.13. Total costs of costliest credits.

	Case 1	Case 2	Case 3	Case 4
Energy Performance	\$20.000	\$155.000	\$10.000	\$10.000
Consultancy Fees	\$80.000	\$30.000	\$20.000	\$20.000
Site Development	\$55.500	\$1.800	\$0	\$31.500
Enhanced Commissioning	\$24.000	\$25.000	\$0	\$0
Certification Fees	\$30.000	\$4.000	\$5.200	\$2.000
Bicycle Storage and Changing Rooms	\$21.000	\$5.000	\$4.600	\$3.200

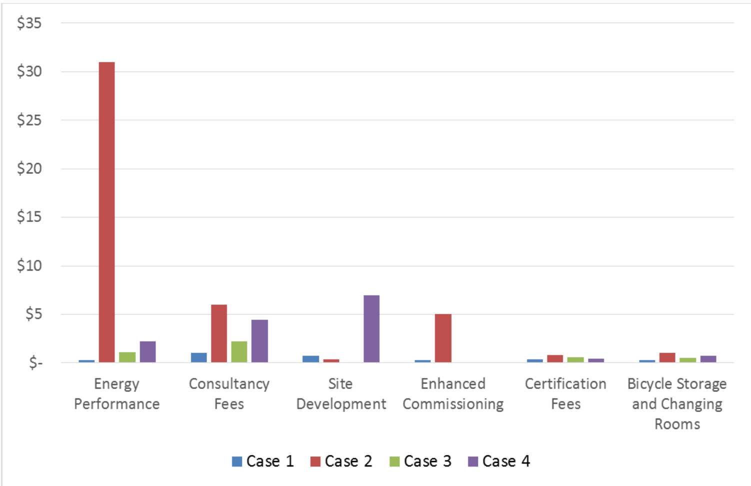

Figure 5.14. Costs per area (\$/m^2) of costliest credits.

Table 5.14. Costs per area (\$/m^2) of costliest credits.

	Case 1	Case 2	Case 3	Case 4
Energy Performance	0.27	31	1.11	2.22
Consultancy Fees	1.07	6	2.22	4.44
Site Development	0.74	0.36	0	7
Enhanced Commissioning	0.32	5	0	0
Certification Fees	0.4	0.8	0.58	0.44
Bicycle Storage and Changing Rooms	0.28	1	0.51	0.71

On the Figure 4.50, costs per area (\$/m^2) of costliest items are presented. Case 2 and Case 4 as the smallest projects have the highest per area costs in all categories.

The main cost gap between LEED Platinum certified Case 1 and Case 2 are resulted from the approach differences to the energy performance. Case 1 spent $20,000 for energy efficiency credit where Case 2 spent $155,000 because of the innovative design approach. Case 1 complied with the water efficiency credit by selecting low flow fixtures without additional costs where Case 2 complied with the credit with grey water treatment system with an additional cost of $20,000. Additionally, Case 2 pursued the renewable energy production credit and spent $24,000 for it where Case 1 didn't apply this credit. These items resulted in a large cost difference between two Cases although both buildings achieve LEED Platinum certification. On the below given tables breakdown of the costs according to credits are presented.

Case 3 and Case 4 have relatively similar costs. However, Case 4 resulted in higher cost since Case 3 is a core and shell building. Case 4 has some cost items such as CO2 sensors and desk lamps which are related to interior finishes. However, the largest cost item of Case 4 is green roof and vegetation. This is a cost depending the concept design. The building had to invest in greening since they didn't have an initial design for green area.

Literature is reviewed to compare these results with other studies. World Business Council for Sustainable Development found that the average reported cost increase is 1.5% as shown on the Figure 2.5 in 2007. The project budget increase for LEED Gold certification is found out as 4 - 7% for these projects according to a study Deloitte conducted in 2008. Costs associated with seeking LEED certification is estimated to be below 2% of the total project cost according to C.Mapp in 2011. Nyikos (2012) collected construction, cost, and utility data of 160 LEED certified buildings and analyzed them using simple correlation and descriptive statistics. It is found that cost premium is ranged from 2.5 to 9.4% with a mean of 4.1%. The findings of another study estimate the excess cost of green building between 0-10% by Gabay (2014), the average rate of 5% is taken for comparison. Results of these studies and the Case studies examined are compared in Figure 5.15.

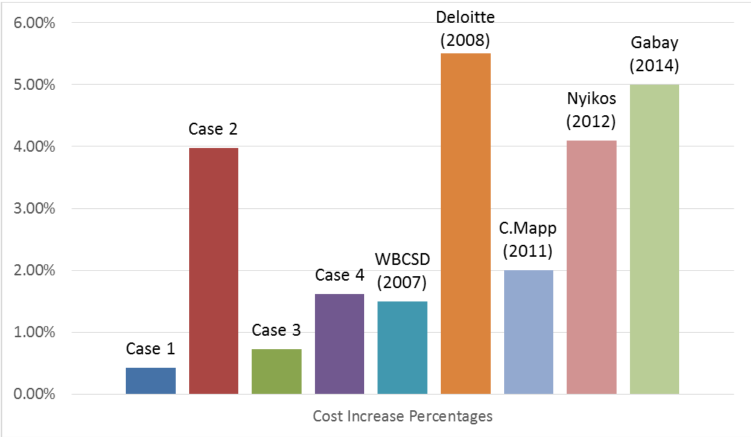

Figure 5.15. Cost premium of Cases and other studies.

Generally, it can be seen that the results of this study is compatible with the results of other studies. This study contributes to the literature in several ways:

- There is evidence that the cost premium of core and shell projects is less than fully built projects.
- The approach of the developer affects the cost premium. The costs increase if the building will be used by the owner.
- Costs of LEED certification vary between 0.4% to 4% in these four Cases.
- LEED certification costs in Turkey are similar to U.S.
- Soft costs of LEED Gold certified projects are almost equal to hard costs. LEED Platinum certified buildings have higher hard costs than soft costs. Consultancy and certification fees occur regardless of the certification level and building size.

6. CONCLUSION

In this study, it is aimed to show the project budget impact of green building implementation. Four LEED certified office buildings are analyzed for this purpose since LEED is the most widely used green building certification system. LEED criteria implemented in these projects are detailly examined in project documents and related costs are investigated with interviews with project team. These four projects are summarized below:

- Case 1: LEED Platinum certified, core and shell, 75,000 m^2, \$60 million,
- Case 2: LEED Platinum certified, fully built, 5,000 m^2, \$7 million,
- Case 3: LEED Gold certified, core and shell, 9,000 m^2 \$7 million
- Case 4: LEED Gold certified, fully built, 4,500 m^2, \$5.5 million

As a result of the study; it is found out that Case 1 had a cost increase of \$256,250 which is 0.43% of total budget and \$3.4/m^2 per area, Case 2 had a cost increase of \$277,950 which is 3.97% of total budget and \$55.6/m^2 per area, Case 3 had a cost increase of \$50,900 which is 0.72% of total budget and \$5.6/m^2 per area, Case 4 had a cost increase of \$88,930 which is 1.6% of total budget and \$19.7/m^2 per area. Costs are categorized in different ways to analyze the results from different perspectives. Firstly, it is seen that LEED Platinum certified projects have larger cost increase compared to LEED Gold certified projects as expected. Total cost increase for Platinum certified projects are between \$250,000 - \$300,000 where project cost increase of Gold certified projects is between \$50,000 - \$100,000.

In terms of cost increase percentages, it is seen that Case 1 and Case 3 had much more lower cost increase than Case 2 and Case 4. Case 1 and Case 3 had a cost increase of 0.43% and 0.72% where Case 2 and Case 4 had 3.97% and 1.6%. The main reason for this is considered to be that Case 1 and Case 3 are core and shell projects. Tenant area which is the large part of the building is left unfinished and not evaluated by LEED certification. Also, owners of Case 1 and Case 3 are both real estate developer companies which aim the most cost-effective way to achieve LEED certification mainly for marketing purposes. On the other hand, the owner of Case 2 is a non-profit organization and Case 4 is located in the largest oil refinery in Turkey. Both of them occupy and actively use the buildings by their selves. Thus, the green building strategies they implement in the buildings are not only meant for LEED certification.

It is found out that criteria included in Energy and Atmosphere and Sustainable Sites categories and costs of consultancy constitute the largest part of cost increase. They can have different cost impacts regarding the project teams approach to the efficiency measures and the existing concept design. Water Efficiency, Materials and Resources and Indoor Environmental Quality categories have less impact on project budget compared to other categories. Generally, green building practices such as green area development, improvement of energy performance, commissioning process, renewable energy production and LEED certification and consultancy fees are the main cost items occurred in these Cases.

In the literature, the LEED certification costs are mainly divided as soft and hard costs. Hard costs are costs related to material purchase, physical implementation of strategies and associated labor. Soft costs include additional paperwork, certification fees, LEED related consultancy fees. Soft costs constitute 60% of total costs in Case 1, 23% in Case 2, 70% in Case 3 and 38% in Case 4. It is seen that soft costs are higher than hard costs in core and shell projects (Case 1 and Case 3) since core and shell projects do not include much construction work. Additionally, the share of soft costs is higher in LEED Gold certified project compared to Platinum certified projects because LEED Platinum projects implement more green building strategies than LEED Gold projects which create hard costs.

LEED credits are also divided into four cost categories, namely, low size-sensitive costs, high size-sensitive costs, costs depending on concept design and negligible costs. The distribution of the credits into these categories are determined for all Cases.

Low size-sensitive costs include measures with a minimum fixed cost and low increase with the project size. These costs are generally associated with third party consulting companies and they are mostly soft costs. Commissioning services and LEED consultancy fees are included in this category. Low size-sensitive costs constitute 41% of total cost impact of Case 1 and 20% in Case 2, 40% in Case 3 and 22% in Case 4.

High size-sensitive costs are proportional with project size and can be considered as fixed costs per area. They constitute 30% of cost impact of Case 1, 3% for Case 2, 39% in Case 3 and 22% in Case 4. These costs include green area development, measures related to construction activities, bicycle storage and showers and LEED certification fees.

Most of the green building criteria and implementation are flexible and open to different approaches. Costs depending concept design include credits which can be fulfilled with different strategies and approaches. Specifically, the goal to design an energy efficient building has many ways. Case 1 implemented the most cost-effective strategies to achieve it such as efficient mechanical equipment, LED lamps, sun shading devices. On the exact opposite, Case 2 implemented innovative and major-scale solutions such as underground air labyrinth, renewable energy production, slab cooling, mesh façade system and grey water re-use. As a result, a major cost increase gap between Case 1 and Case 2 is created even though they achieved the same level of certification. Cost increase due the concept design depending credits are 30% in Case 1 and 77% in Case 2. Similarly, concept design depending costs of Case 3 constitutes only 20% where it constitutes 55% in Case 4. Case 4 implemented additional green roof, vegetated area and individual lighting equipment where Case 3 did not need to do these improvements.

Some green building properties create negligible costs which are considered as "no costs" in this study. These include criteria that are met without green building consideration such as site proximity to public transport, surrounding development density and criteria that are incorporated into the contractor's specifications without additional costs such as low emitting material selection, regional materials, construction waste management. These items constitute approximately 20% of LEED credits and all Cases earned all points in these credits.

Considering these findings, it can be concluded that the impact of green building implementation on the project budget mainly depends the following three items: Level of desired certification, scope of construction work (whether it is core and shell or fully built building) and initial concept design before consideration of certification.

According to conclusions drawn in this study, it can be advised that in order to reduce the LEED certification costs it is important to define initial concept design according to green building strategies specially measures such as energy efficiency and green area. Architectural strategies such as correct building orientation, sun shading devices, better insulation rates and more green area on the site and roof can be included in the design as cost effective ways to achieve LEED certification. Mechanical design should consider energy efficiency in the preliminary design in order to increase energy efficiency less costly. It seen that innovative energy efficiency measures such as underground ventilation and PV panels increase costs more than traditional strategies such as better HVAC system and equipment selection. Project teams aiming for a green building should consider these findings.

It is found out that green building costs in core and shell projects are lower than fully built projects. Thus, green building performance that LEED certification mandates for core and shell projects seems to be lower than other project types. It is advised that LEED certification should mandate tenants to implement the related green building strategies in order to achieve same performance as other project types.

There is significant difference between cost increase of LEED Gold and LEED Platinum certified projects. LEED Gold requires 60 points out of 110 where Platinum requires 80 out of 110. Green building implementation is LEED Platinum buildings are much stronger than LEED Gold buildings as seen in this study. It is likely that green building properties are lesser in lower levels such as LEED Silver and LEED Certified. It is important for the public and construction sector to know the difference between

LEED certification levels and evaluate the value of the buildings accordingly.

6.1. Recommendation for future work

The first cost increase of green buildings is focused in this thesis which constitutes the project budget impact. Maintenance costs of green building practices and utility savings of water and electricity are not included in this thesis. A study which focuses on the financial impact during buildings life is recommended in order to evaluate life-cycle costs completely.

One of the findings of this study is that core and shell buildings are less costly to certify than fully built buildings. However, green building performance of them are not compared in this study. It is recommended to study the green building performance of core and shell projects compered to fully built projects.

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APPENDIX A: Ronesans Kucukyali Office Park

Table A.1. Questionnaire of Case 1, Ronesans Kucukyali Office Park.

Thesis Study Questionnaire **Ronesans Kucukyali Office Park** Please explain the green building implementation and related cost items for each achieved LEED credit listed below:				
Credit Number/Name		**Green Building Implementation**	**Cost Items**	**Costs (USD)**
Sustainable Sites				
Prereq 1	Construction Activity Pollution Prevention			
Credit 1	Site Selection			
Credit 2	Development Density and Community Connectivity			
Credit 4.1	Alternative Transportation-Public Transportation Access			
Credit 4.2	Alternative Transportation-Bicycle Storage and Changing Rooms			
Credit 4.3	Alternative Transportation-Low-Emitting and Fuel-Efficient Vehicles			
Credit 4.4	Alternative Transportation-Parking Capacity			

Table A.1. Questionnaire of Case 1, Ronesans Kucukyali Office Park (cont.).

Thesis Study Questionnaire **Ronesans Kucukyali Office Park** Please explain the green building implementation and related cost items for each achieved LEED credit listed below:				
Credit Number/Name		**Green Building Implementation**	**Cost Items**	**Costs (USD)**
Credit 5.1	Site Development-Protect or Restore Habitat			
Credit 5.2	Site Development-Maximize Open Space			
Credit 6.1	Stormwater Design-Quantity Control			
Credit 7.1	Heat Island Effect-Non-roof			
Credit 7.2	Heat Island Effect-Roof			
Credit 9	Tenant Design and Construction Guidelines			
Water Efficiency				
Prereq 1	Water Use Reduction-20% Reduction			
Credit 1	Water Efficient Landscaping			
Credit 2	Innovative Wastewater Technologies			
Credit 3	Water Use Reduction			

Table A.1. Questionnaire of Case 1, Ronesans Kucukyali Office Park (cont.).

Thesis Study Questionnaire **Ronesans Kucukyali Office Park** Please explain the green building implementation and related cost items for each achieved LEED credit listed below:				
Credit Number/Name		**Green Building Implementation**	**Cost Items**	**Costs (USD)**
Energy and Atmosphere				
Prereq 1	Fundamental Commissioning of Building Energy Systems			
Prereq 2	Minimum Energy Performance			
Prereq 3	Fundamental Refrigerant Management			
Credit 1	Optimize Energy Performance			
Credit 3	Enhanced Commissioning			
Credit 4	Enhanced Refrigerant Management			
Credit 5.1	Measurement and Verification-Base Building			
Credit 5.2	Measurement and Verification-Tenant Submetering			
Materials and Resources				
Prereq 1	Storage and Collection of Recyclables			
Credit 2	Construction Waste Management			
Credit 4	Recycled Content			
Credit 5	Regional Materials			
Credit 6	Certified Wood			

Table A.1. Questionnaire of Case 1, Ronesans Kucukyali Office Park (cont.).

Thesis Study Questionnaire **Ronesans Kucukyali Office Park** Please explain the green building implementation and related cost items for each achieved LEED credit listed below:				
Credit Number/Name		**Green Building Implementation**	**Cost Items**	**Costs (USD)**
Indoor Environmental Quality				
Prereq 1	Minimum Indoor Air Quality Performance			
Prereq 2	Environmental Tobacco Smoke (ETS) Control			
Credit 1	Outdoor Air Delivery Monitoring			
Credit 2	Increased Ventilation			
Credit 3	Construction Indoor Air Quality Management Plan-During Construction			
Credit 4.1	Low-Emitting Materials-Adhesives and Sealants			
Credit 4.2	Low-Emitting Materials-Paints and Coatings			
Credit 4.3	Low-Emitting Materials-Flooring Systems			
Credit 5	Indoor Chemical and Pollutant Source Control			
Credit 7	Thermal Comfort-Design			

Table A.1. Questionnaire of Case 1, Ronesans Kucukyali Office Park (cont.).

Thesis Study Questionnaire **Ronesans Kucukyali Office Park** Please explain the green building implementation and related cost items for each achieved LEED credit listed below:				
Credit Number/Name		**Green Building Implementation**	**Cost Items**	**Costs (USD)**
Credit 8.1	Daylight and Views- Daylight			
Credit 8.2	Daylight and Views- Views			
Innovation and Design				
Credit 1	Innovation in Design: Specific Title			
Credit 2	LEED Accredited Professional			
Regional Priority				
Credit 1	Regional Priority: Specific Credit			
LEED Certification Fees				
Consultancy Fees				

APPENDIX B: Turkish Contractors Headquarters Building

Table B.1. Questionnaire of Case 2, Turkish Contractors Headquarters.

Thesis Study Questionnaire Turkish Contractors Headquarters Building Project Please explain the green building implementation and related cost items for each achieved LEED credit listed below:				
Credit Number/Name		**Green Building Implementation**	**Cost Items**	**Costs (USD)**
Sustainable Sites				
Prereq 1	Construction Activity Pollution Prevention			
Credit 1	Site Selection			
Credit 2	Development Density and Community Connectivity			
Credit 4.1	Alternative Transportation-Public Transportation Access			
Credit 4.2	Alternative Transportation-Bicycle Storage and Changing Rooms			
Credit 4.3	Alternative Transportation-Low-Emitting and Fuel-Efficient Vehicles			
Credit 4.4	Alternative Transportation-Parking Capacity			

Table A.2. Questionnaire of Case 2, Turkish Contractors Headquarters Building (cont.).

Thesis Study Questionnaire **Turkish Contractors Headquarters** **Building Project** Please explain the green building implementation and related cost items for each achieved LEED credit listed below:				
Credit Number/Name		**Green Building Implementation**	**Cost Items**	**Costs (USD)**
Credit 5.1	Site Development-Protect or Restore Habitat			
Credit 5.2	Site Development-Maximize Open Space			
Credit 6.1	Stormwater Design-Quantity Control			
Credit 7.1	Heat Island Effect-Non-roof			
Credit 7.2	Heat Island Effect-Roof			
Credit 9	Tenant Design and Construction Guidelines			
Water Efficiency				
Prereq 1	Water Use Reduction-20% Reduction			
Credit 1	Water Efficient Landscaping			
Credit 2	Innovative Wastewater Technologies			

Table A.2. Questionnaire of Case 2, Turkish Contractors Headquarters Building (cont.).

Thesis Study Questionnaire **Turkish Contractors Headquarters** **Building Project** Please explain the green building implementation and related cost items for each achieved LEED credit listed below:				
Credit Number/Name		**Green Building Implementation**	**Cost Items**	**Costs (USD)**
Credit 3	Water Use Reduction			
Energy and Atmosphere				
Prereq 1	Fundamental Commissioning of Building Energy Systems			
Prereq 2	Minimum Energy Performance			
Prereq 3	Fundamental Refrigerant Management			
Credit 1	Optimize Energy Performance			
Credit 3	Enhanced Commissioning			
Credit 4	Enhanced Refrigerant Management			
Credit 5.1	Measurement and Verification-Base Building			
Credit 5.2	Measurement and Verification-Tenant Submetering			
Materials and Resources				
Prereq 1	Storage and Collection of Recyclables			
Credit 2	Construction Waste Management			
Credit 4	Recycled Content			

Table A.2. Questionnaire of Case 2, Turkish Contractors Headquarters Building (cont.).

Thesis Study Questionnaire Turkish Contractors Headquarters Building Project Please explain the green building implementation and related cost items for each achieved LEED credit listed below:				
Credit Number/Name		**Green Building Implementation**	**Cost Items**	**Costs (USD)**
Credit 5	Regional Materials			
Credit 6	Certified Wood			
Indoor Environmental Quality				
Prereq 1	Minimum Indoor Air Quality Performance			
Prereq 2	Environmental Tobacco Smoke (ETS) Control			
Credit 1	Outdoor Air Delivery Monitoring			
Credit 2	Increased Ventilation			
Credit 3	Construction Indoor Air Quality Management Plan-During Construction			
Credit 4.1	Low-Emitting Materials-Adhesives and Sealants			
Credit 4.2	Low-Emitting Materials-Paints and Coatings			
Credit 4.3	Low-Emitting Materials-Flooring Systems			

Table A.2. Questionnaire of Case 2, Turkish Contractors Headquarters Building (cont.).

Thesis Study Questionnaire Turkish Contractors Headquarters Building Project Please explain the green building implementation and related cost items for each achieved LEED credit listed below:				
Credit Number/Name		**Green Building Implementation**	**Cost Items**	**Costs (USD)**
Credit 5	Indoor Chemical and Pollutant Source Control			
Credit 7	Thermal Comfort-Design			
Credit 8.1	Daylight and Views-Daylight			
Credit 8.2	Daylight and Views-Views			
Innovation and Design				
Credit 1	Innovation in Design: Specific Title			
Credit 2	LEED Accredited Professional			
Regional Priority				
Credit 1	Regional Priority: Specific Credit			
LEED Certification Fees				
Consultancy Fees				