ANALYZING LEED WITH COMPARISON TO OTHER BUILDING ASSESSMENT SYSTEMS: CALIFORNIA ACADEMY OF SCIENCES AS A CASE STUDY

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ABSTRACT

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Nowadays, climate change and other related environmental effects of it are one of the major topics that human beings closely related with; not only with technological concerns but also with social concerns. These environmental changes of our World led us to construct new topics and building systems that integrates with nature not rejects it; ecological design, green architecture, eco-efficient design, etc… Building assessment systems are the selected tools in achieving these keywords. Throughout the history of sustainable design, many building assessment systems that rate the selected building's efficiency in terms of environmental aspects (like the material selection, energy use in operating the building, etc…) came on the scene. The aim of the thesis is to clarify the advantages of Leadership in Energy and Environmental Design (LEED) building assessment system on other used building assessment systems in different countries. With the help of a case study of California Academy of Sciences by Renzo Piano and rating it with other building assessment systems, the thesis supports the idea that LEED is the most wide-spread used building assessment system among other systems with its simplicity, user-friendliness and flexibility.

Keywords: Sustainable Development, Building Assessment Systems, LEED, California Academy of Sciences

ÖZET

LEED BİNA DEĞERLENDİRME SİSTEMİNİ DİĞER SİSTEMLERLE KARŞILAŞTIRMALI ANALİZ ETMEK: ÖRNEK ALAN ÇALIŞMASI OLARAK CALIFORNIA ACADEMY OF SCIENCES

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Yaşanan iklimsel değişiklikler ve buna bağlı yaşanan çevresel sonuçlar günümüzde insanlığın uğraştığı en önemli sorunlardan biri durumundadır. Bu iklimsel değişiklikler bizi çevreyle uyumlu çalışacak yeni yapım yöntemleri oluşturmaya yöneltmiştir. Ekolojik tasarım, yeşil mimari, eko-efektif tasarım bu yeni oluşturulan terimlerden birkaçıdır. Sosyal ve etik yaşantılarımızı yeniden kurgulamamızın yolu öncelikle bizi çevreleyen yapıları yeniden kurgulamamız ile bağlantılıdır. Bu bağlamda bize yol gösterecek olan ise Bina Değerlendirme Sistemleridir. Kavramın tarihsel gelişiminde yapıların çevresel yönden verimliliklerini notlayan birçok değerlendirme sistemi olmuştur. Leadership in Energy and Environmental Design (LEED) bina değerlendirme sistemi ise basit, kolay kullanılabilir ara yüzü ve geliştirmeye açık yapısal tasarımı sayesinde günümüzde kullanılan ve tez içerisinde incelenen diğer değerlendirme sistemlerinden ayrılmaktadır. Tezin amacı, LEED in diğer bina değerlendirme sistemleri üzerindeki bahsedilen avantajlarını seçilen örnek alan çalışması California Academy of Sciences binası yardımıyla öne çıkarmaktır.

Anahtar Kelimeler: Sürdürülebilir Gelişim, Bina Değerlendirme Sistemleri, LEED, California Academy of Sciences

To My Parents

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INTRODUCTION

1.1. Problem Definition & Aim of the Study

The importance of sustainable design is gaining importance as the society is aware of a new threat: global warming and its effects on our surroundings. In this sense, the society is in need of some standardizations like building assessment systems that simply rate the selected building's performance in terms of sustainable criterions. There are many used building assessment systems throughout the world. In this thesis the focus will be on LEED (Leadership in Energy and Environmental Design), with comparison to other three selected building assessment systems: BREEAM, CASBEE and GreenStar. Within these four different assessment systems, the advantages of LEED on others will be clarified through comparisons with the help of a case study in the end: California Academy of Sciences. The major advantages of LEED such as its simplicity, user friendliness and flexibility will be the important aspects for this thesis; as these aspects make LEED as a wide-spread used building assessment system. These major advantages also help LEED to turn into the most wide-spread used building assessment system in time.

The roots of implementation of building assessment systems can be traced within the history of sustainable design and a brief history on this area is crucial as new emerging forces are reshaping the building construction industry. These factors force professionals to reconsider their roles in the building construction and delivery process. According to Beatley, the main impetus of this is the sustainable development movements, which is changing both physically structures and minds of individuals who inhabit it (Beatley, 1997).

Briefly climate change is caused by increasing concentrations of human-generated carbon dioxide, methane and other gases in the atmosphere. Through this progress, inadequate consideration is given to how human activity and building construction industry should adopt to climate changes. Global warming should be considered as a factor, input while structuring our surroundings by using ecological design, passive design, the building envelope (Kilbert, 1994).

With this implication, a unique vocabulary is emerging to describe concepts related to sustainable design and environmental changes. Terms like ecological footprint, ecological rucksack, biomimicry, the natural step, eco-efficiency, and ecological economics describe the basic concepts in terms of sustainable design.

There are also some terms that can be seen as complementary terms such as, green building, building assessment systems, ecological design, life-cycle assessment, life-cycle costing. A high-performance building should articulate and use these specific techniques in the design process for the sake of a sustainably built environment (Kilbert, 2005). This sustainable development movement has been evolving worldwide for decades, causing significant changes in building delivery systems in a relatively short period of time. Briefly, sustainable construction addresses the role of the built environment in contributing to the overarching vision of sustainability.

This movement of sustainable development had also several effects on building construction. Nowadays building assessment systems seem to have a great importance in the industry. These systems basically look into the building delivery and note the materials, systems used to construct that specific building according to their specific credit system. These kinds of systems turned into a must for building owners in order to prove that their building is sustainable and is a key point in the process of sustainable development. These systems rate buildings' design and delivery with regard to sustainable aspects by using credits for each sub-category in their list of categories. Each building assessment system has different sub categories for credits – points – and a different sum of points at the end of each assessment. This point system is important as it is very simple and effective to rate a building using some sub-categories. Through these assessment systems, it can be asserted that LEED is the foremost one, but there are also other building assessment systems in the world like BREEAM, CASBEE, Green Star, etc.

According to USGBC, LEED system removed ambiguity in the concepts related with sustainability and green building construction. LEED's newly emerging assessment standard rapidly gained acceptance in both the private and public sectors and significantly changed the building construction industry. By the end of 2004, there were 121 LEED certified buildings and over 1400 undergoing certification in the United States (USGBC, 2009). There are also other building assessment systems developed and being used in other countries but the predominant building assessment system in the U.S. is LEED building assessment system. Besides its use in U.S., LEED building assessment system has also been adopted to several different countries like Spain, Canada and China with some additional modifications on the structure of the system (Kilbert, 2005).

This thesis aims to intensify LEED building assessment system with comparison to other building assessment systems with an additional analysis of the selected case study – California Academy of Sciences by Renzo Piano. The thesis will contribute the literature on considering other wide-spread used building assessment systems with regard to LEED. Making comparisons between these selected building assessment systems and analyzing the results why LEED is the most wide-spread used building assessment system throughout the these systems by looking at the selected case study, is also crucial for the thesis. This case study will also be rated with BREEAM, CASBEE and GreenStar building assessment systems and the results will clarify why LEED is the foremost and wide-spread used assessment system around the world; as rating the same selected building with other building assessment systems will show the general structure and foremost advantages and disadvantages of each assessment system in a practical way.

The thesis will also look at the importance of building assessment systems in pursuit of a sustainably developed society. Building assessment systems will be discussed and analysed starting from the historical background and foundations of these systems. Nowadays LEED is the foremost building assessment system used to rate the efficiency of a building in terms of sustainable design. Its simple scoring system and categorization of points – details of points are included on a separate book that can be provided from USGBC (U.S. Green Building Council) - makes this system a wide-spread used system because it is easy for design teams and owners of the buildings to understand. This simplicity also gives the advantage of including additions to the structure of the system and versions of the systems are releasing frequently.

LEED is developed as a building assessment standard by USGBC and it is widely used in U.S. The hypothesis is that, LEED is a wide-spread used building assessment system because of its simplicity and flexibility which makes LEED a wide-spread used building assessment system among other systems. To make this hypothesis clear, the case study will be analyzed – California Academy of Sciences by Renzo Piano – and additional assessments of the case study with LEED, BREEAM, CASBEE, GreenStar will be made to clarify the advantages of LEED on other systems.

1.2. Literature Review & Methodology

To help and guide the thesis to its aim, major books, theses and articles were considered to clarify the path of the thesis. There is an ongoing argument on the needs of building assessment systems in the literature which also questions whether these systems are helpful or not in terms of sustainable development. These discussions also contain comparisons of major building assessment systems. But no theses or articles have compared these four assessment systems; LEED, BREEAM, CASBEE and GreenStar, with each other as this thesis do. The comparison of these four building assessment systems being used in different four continents will be helpful to create an opinion on the diversity of building assessment systems in different continents.

The Guidebook to Sustainable Design by Sandra Mendler, William Odell and Mary Ann Lazarus is a primary source that basically handles the topic sustainable construction from its starting point, gives some examples and considers building assessment systems; not only LEED but also other building assessment systems by analysing these topics on some major case studies. The book Sustainable Construction by Charles J. Kilbert had also great inputs on the thesis as it is more focused on the LEED building assessment system.

The articles “Green Building Assessment Systems” by Rebecca C. Retzlaff, Sustainable by Design by Ajay Garde, “Comparative Assessment of Environmental Performance Tools and the Role of the Green Building Challenge” by Joel Ann Todd, Drury Crawley, Susanne Geissler and Gail Lindsey have inputs on the understanding of these building assessment systems. The article "Green Building Assessment Systems: A Framework and Comparison for Planners" by Rebecca C. Retzlaff provided the major comparison inputs for the thesis that will be analyzed in the comparison section of the thesis. The comparisons and the tables constructed through these articles gave a starting point for this thesis.

Throughout the literature review of this thesis, examples from Turkey were also taken part as two theses concentrated on LEED. These two theses led the thesis in comparing the selected building assessment systems with each other. The thesis "Assessment of Intelligent Buildings in Terms of Environmental Sustainability" by Ulaş Civan created a basis for the comparison chapter of this thesis. Since no theses or articles compared the four selected building assessment systems – LEED, BREEAM, CASBEE and GreenStar – the impetus from Ulaş Civan's thesis created a base point for Chapter 3. The other thesis from Turkey, "Assessment on Green Building Rating Systems and Their Adaptations to Turkey" by Elif Çelik maintained some valuable data especially for the building assessment systems LEED and BREEAM. The detailed explanations on each credit of their assessment categories are included in Elif Çelik's thesis.

The articles "Integrating The Natural Step to LEED" by Alex Zimmerman and "Integrating LCA Tools in Green Building Rating Systems" by Wayne B. Trusty gave a much more wider view of the topic considering the modifications that can be made on LEED.

Among literature, there are some studies on comparing building assessment systems with each other. But what makes this thesis original is the comparison of LEED with other major building assessment systems like BREEAM, CASBEE, GreenStar. These selected building assessment systems also reflect the diversity of these systems as they are used in different continents of the world to create a sustainably developed world in the process of sustainable design.

LEED building assessment systems is not a perfect assessment system and there is an ongoing discussion on improving LEED with some modifications and integrations of Life Cycle Assessment tools and The Natural Step systems. In order to support these ideas, first the major advantages of LEED should be clarified with regard to other used building assessment systems. But these integrations and modifications to be made on LEED, is out of boundaries of this thesis as this thesis concentrates why LEED is the dominant building assessment system among other building assessment systems; in this sense analyzing the advantages of LEED on these systems is crucial where the selected case study will also help to guide the thesis in this direction.

The thesis will use comparisons among building assessment systems to clarify its aim – the advantages of LEED on other system and put forward why LEED is the wide-spread used building assessment system among these systems. After comparing major building assessment systems with LEED, a case study, California Academy of Sciences will be analyzed by using LEED, BREEAM, CASBEE and GreenStar building assessment systems. The required connection was made with the office of Renzo Piano (Renzo Piano Building Workshop) and technical drawings (plans, sections, details) were gathered from their office to guide Chapter 4. Additional images to support the assessment of the case study are maintained through internet.

In order to clarify the advantages of LEED on other building assessment systems, the comparisons to be made is crucial and the methodology of these comparisons were structured on the criteria of general informations (date, country, use, versions, assessment categories and the scoring systems of the systems). This division of sub-categories will enable to draw solid and simple conclusions in the end of Chapter 3.

1.3. Content

Besides LEED, some other major building assessment systems used throughout the world will be analyzed briefly in the thesis. Analysing and understanding other building assessment systems will create a better understanding of why LEED is the chosen assessment system to be improved through this thesis. BREEAM (UK), CASBEE (Japan), GreenStar (Australia) are the systems analyzed briefly in this sense. But because of its simplicity, wide-spread usage and its flexibility on modifications; LEED is the chosen building system to be discussed and criticised more. Chapter 2 will focus on the analyses of these four building assessment systems, their historical background, assessment categories and scoring systems.

In this sense, the historical background of LEED will be discussed to give a better understanding on its foundations. The structure of LEED will be the next point to be analyzed in the following sections of Chapter 2. The credit system of LEED will be explained and credits according to categories will be mentioned to give the main idea of this building assessment system.

Since LEED is the chosen building assessment system for the sake of sustainable development era, the comparisons between building assessment systems and LEED will be the next point to be mentioned in the thesis. In this sense, LEED will be compared with other selected building assessment systems, BREEAM (UK), CASBEE (Japan), GreenStar (Australia). With the help of these comparisons, LEED assessment system will be analyzed in a more detailed way in Chapter 3.

These comparisons on chapter 3 will be made on some separate sub-chapters; based on their general properties (their versions date and use field), assessment categories and scoring systems. These comparisons will be followed by a collective conclusion in the end of Chapter 3.

Examining LEED and other building assessment systems is not sufficient enough; therefore an analysis of a selected case study will be next point of Chapter 4. To give a more detailed view of these systems, having a case study is crucial and it is the next point to be mentioned in the thesis. In this sense California Academy of Sciences by Renzo Piano is selected and will be analyzed and discussed in a separate chapter. Since California Academy of Sciences is rated by LEED and gained LEED Platinum certification, its implementation in the thesis is crucial. Because its scoring sheet gained from USGBC is accessible, the comparisons and analysis to be made will be more scientifically. It is a recent project made by a Pritzker winner architect which will also give a better understanding of the contributions made by architects for the sake of a sustainable society.

Additional assessments using BREEAM, CASBEE and GreenStar building assessment systems will also be made using the charts and data from the Chapter 3 to give a better understanding on the field and answer the question if these kinds of systems were used to rate the selected building what would occur in terms of assessment and certification.

The findings will in the end clarify why LEED is the most wide-spread used building assessment system among other assessment systems with the impetus on its simplicity. In this sense LEED is the chosen standard to direct us to a more sustainable surrounding and the main idea of this thesis is to analyze LEED, compare it with other building assessment tools and intensify the findings on the selected case study to clarify the advantages of LEED building assessment system on other building assessment systems.

CHAPTER 2

BUILDING ASSESSMENT SYSTEMS

The built environment has direct, complex and long lasting impacts on the biosphere throughout a few decades. The productions of building components harm the natural habitat. The response to these issues is the green building movement. This green building term refers to the qualities and characteristics of the structure created using the main principles of sustainable construction. These green buildings can briefly be defined as structures designed and built in a way using sustainability principles (Yudelson, 2007). Ecological design, ecologically sustainable design, sustainable design and green design are the similar terms that describe the application of sustainability principles into the building design.

Through this history of green building movement, there are some key organizations (mainly in U.S.) promoting the implementation of sustainable construction practices which include the U.S. Green Building Council, the U.S. Department of Energy, the U.S. Environmental Protection Agency, and other public agencies and companies. The main green building organization in the U.S. is the U.S. Green Building Council (USGBC) and their building assessment system LEED (Leadership in Energy and Environmental Design) is the building assessment system that is most wide-spread used assessment system in U.S. Since its implementation, the number of LEED certified buildings had increased each year which included an increase in the size of the buildings, too (Kilbert, 2005).

In order to achieve the goal of sustainable environment, it is crucial to assess the structures and buildings that surround us. In this sense building assessment systems; whether it is LEED or other building assessment systems used worldwide; is an advantage on the development of a sustainable society. These assessment systems simply analyse the building with its structure and in the end rates it in terms of sustainability. As the number of buildings to be rated with these assessment systems increases in number, we would have a better and sustainable society that surrounds us and has minimum environmental effects.

Analysing and describing these building assessment systems will be the focal point of this chapter starting from their historical background. These definitions of building systems will be followed by comparisons among them to give a better understanding on how these systems function and will help to clarify the advantages and disadvantages of each system.

2.1. Historical Background

The historical background of building assessment systems is the next important topic after giving a general view about building assessment systems. The starting point of this movement will give us an idea about sustainable construction not only focusing on U.S. led by LEED but also the background of other used building assessment systems.

The history of international green building movement started in early 1990s. In 1992, *Conseil International du Batiment* (CIB) Task Group 8 on Building Assessment, provided crucial inputs for the development of building assessment systems. CIB Task Group 16 also had inputs especially on Sustainable Construction which in the end help to intensify basic standards focussing on the application of sustainability principles to the built environment that surrounds us (Kilbert, 2005).

The Green Building Movement in U.S. has a long history starting from the late 19^{th} century. There was a growing interest on energy and resource conservation on issues such as ozone depletion, climate change, etc. Three events in the late 1980s and early 1990s helped to focus on environmental problems: the publication "Our Common Future" in 1987, commonly referred as the Bruntland Report, the 1989 meeting of the American Institute of Architects (AIA) and the United Nations Conference on Sustainable Development in 1992, the Rio Conference (Kilbert, 2005). But the main factor that facilitated to articulate a code of principles for sustainable development was held in 1993 by meeting of the International Union of Architects (UIA) and the AIA. The UIA/AIA combined congress ended with the "Declaration of Independence for a Sustainable Future" that shaped the main principles for sustainable design (Cole, 2006).

The earliest examples of green buildings were the results of major U.S. environmental organizations requiring for sustainable approaches. In 1985, William McDonough was hired by the Environmental Defence Fund to design its New York offices. The design included natural materials, daylighting and excellent indoor environmental quality. In 1989, the Croxton Collaborative designed the offices of the Natural Resources Defence Council. The 1992 renovation of Audubon House was a significant effort in the contemporary green building movement that became a hallmark of the contemporary green building process (Lützkendorf, 2006). The first highly publicized green building project in the U.S. was the Greening of the White House in 1993 (Kilbert, 2005). The success of the White House project facilitated the federal government's sustainability efforts and forced the U.S. Post Office, the Pentagon, the Department of Energy and Government Services Administration to address sustainability concerns within their organizations. The U.S. Navy's construction and Naval Facilities Engineering Command (NAVFAC) began a series of eight pilot projects to address sustainability and energy conservation concerns within this period (Stein, 2004).

More important guides to green building appeared in the early to mid 1990s. The Environmental Building News, first published in 1992, remained its position as an independent guide to sustainable construction. In 1994, the AIA first published its

Environmental Resources Guide followed by a detailed version in 1996. "The Guiding Principles for Sustainable Design" structured by the National Park Service in 1994, provided one of the first overviews of green building production. "The Sustainable Building Technical Manual" that is developed by the U.S. Department of Energy and Public Technology Inc. in 1996 was also an important guide for sustainable development (Kilbert, 2005).

There were also some other international efforts and organizations interacted and influenced the U.S. movement during this period. The British green building rating system, the Building Research Establishment Environmental Assessment Method (BREEAM) was developed in 1992. Early articulations of LEED building assessment system started to appear at this time. Development of USGBC's LEED building assessment system took four years and a preliminary version known as LEED Version 1.0 took place in 1998 (Lazarus, 2006). It was a very successful effort that in the end the Federal Energy Management Program sponsored this new emerging building assessment system to test its assumptions in some of their buildings. An improved LEED version 2.0 was launched in 2000, followed by a further version LEED 2.1 that was launched in 2003 with the changing of the lowest "Bronze" certification level to "Certified". And now design teams and building owners have LEED version 3.0 with its additional online support and credits in its assessment categories (Bower, 2006).

The historical progress of building assessment systems seem to be focus more on U.S. with its first implementations of it. Before starting to analyse LEED, a wider point of view is needed and in this sense other major building assessment systems will be considered.

2.2. Building Assessment Systems

The green building movement is a recent phenomenon, which is growing at an exponential rate. The LEED building assessment standard has emerged as the definite guideline. It articulates the parameters for green buildings in U.S. and other countries. But in order to understand the major advantages of LEED better, it would be helpful to first look at some other used building assessment systems such as BREEAM (United Kingdom), CASBEE (Japan) and GreenStar (Australia).

2.2.1. BREEAM (UK)

BREEAM (Building Research Establishment Environmental Assessment Method), is the oldest building assessment system and the most wide-spread used one until the arrival of LEED. Its development was initiated in 1988 by Building Research Establishment (BRE) to help transforming the construction of office buildings to high performance standards. BREEAM building assessment system has also been adopted in Canada and several European and Asian countries (Kilbert, 2005). BREEAM Buildings can be used to assess the environmental performance of almost any type of building whether they are new or existing. Buildings outside UK can also be assessed using BREEAM International version of this assessment system (http://www.breeam.org, 2010). BREEAM has also sub-categories for different types of buildings for assessment such as BREEAM

Other Buildings, BREEAM Courts, BREEAM Ecohomes, BREEAM Healthcare, BREEAM Industrial, BREEAM International, BREEAM Multi-residential, BREEAM Prisons, BREEAM Offices, BREEAM Retail, BREEAM Education, BREEAM Communities, BREEAM Domestic Refurbishment (http://www.breeam.org, 2010). These sub-categories are very similar to the ones used in LEED building assessment system. CASBEE also uses a similar logic in terms of buildings types but its categorization is much simpler than BREEAM and LEED.

These covered assessment areas of BREEAM clarifies that, this building assessment system is also a wide-spread used building assessment system as it covers many issues on sustainable construction like LEED building assessment system (Dickie, 2000). Because of its consideration on both material selection, energy use and management areas, this building assessment system could be considered as a parent of LEED and is one of the wide-spread used building assessment system used in different countries with LEED.

In BREEAM, a set of environmental weightings enable the credits to be added together to produce a single overall score. In the end, the building is rated as Pass, Good, Very Good and Excellent. In addition, a separate certificate is rewarded that can be used for promotional purposes. This building assessment system covers primarily offices, homes and industrial units as well as urban spaces to prisons (http://www.breeam.org, 2010).

Table 2.1. BREEAM Categories (http://www.breeam.org, 2010)

Categories	**Points**
Management	13
Health & Wellbeing	13
Energy	26
Transport	10
Water	6
Materials	13
Waste	9
Land Use & Ecology	10
Pollution	14
Innovation	10

In order to understand BREEAM better and have a clear view on its scoring categories, the next point will be to consider each scoring category of BREEAM separately with regard to their point weightings. Through these assessment categories of BREEAM, Energy category has the highest possible points as it is very crucial for a sustainable building to be energy efficient. Other assessment categories have almost the same possible points that show the given importance of each category by BREEAM officers.

Table 2.2. Management: 13 Possible Points (http://www.breeam.org, 2010)

Credit Description	**Point**
Commissioning	2
Considerate Constructors	2
Construction Site Impacts	4
Building User Guide	1
Site Investigation	1
Consultation	1
Shared facilities	1
Security	1

Management scoring category of BREEAM mainly covers the management of construction phase of the building in terms of its site investigation and impact to the nature during excavation of the site. As can be read from the table, construction site impact seems to be the most important criteria as it has possible 4 points in this category.

In addition to these issues, commissioning and considering constructors are also other important issues which increase the consideration of knowledge management in different fields of construction. Building user guide enables building owners to have a guidebook of BREEAM that explains each category and their needed data briefly and having one of this guidebook also has an additional point in this assessment category. Consultation point is also important as to become a sustainable building both for occupants and owners, major consultation is needed to get interdisciplinary knowledge (Çelik, 2009).

Consultation between these aspects of construction will create a bond for the completetion of the building. In this category, the issue of Security is also in scene, both in the construction phase (the security of the workers) and the occupants to use the facility after its construction phase (http://www.breeam.org, 2010).

Site investigation point summarizes the site improvements of the project during its construction phase. Before construction, a clarified investigation of the site is needed to get this point. This investigation involves, the analyses of the topography, water sources, wild-life, bio-diversity of the location, access, etc (http://www.breeam.org, 2010).

Table 2.3. Health & Wellbeing: 13 Possible Points (http://www.breeam.org, 2010)

Credit Description	**Point**
Daylighting	1
View Out	1
Glare Control	1
High frequency lighting	1
Internal and external lighting levels	1
Lighting zones and controls	1
Potential for Natural Ventilation	1
Indoor Air Quality	1
Volatile Organic Compounds	1
Thermal Comfort	1
Thermal Zoning	1
Microbial Contamination	1
Acoustic Performance	1

Health and wellbeing scoring category with its possible 13 points evaluates the performance of the building (starting from its construction) in terms of health and comfort issues. In this sense, daylighting, thermal comfort, air quality, lighting and acoustics are the main issues of this category as they have a great impact on the building. This scoring category concentrates on the comfort of the occupants of the building and assesses the building in this sense.

Some points in this assessment category could confuse the design teams as they are not familiar with this kind of assessment in different issues of Health and Wellbeing category. In general first six points in this assessment category gives importance on the lighting properties of the building from the eyes of the occupants. Glare control, high frequency lighting points concentrates on the health of the occupants as high frequency lighting and glare could harm the retina. Internal and external lighting levels point rates the adequate lighting level needed for that specific facility of the building (Grace, 2000).

The next issue for this assessment category is the indoor air quality of the building. It is also an important issue for the healths of the occupants and visitors of the building. Ventilation is crucial in this sense and related point rates whether adequate fresh air needed is entered to the building or not. Volatile organic compounds point could be confusing as it is not an every-day issue to be faced but is crucial within this category. Volatile compounds have the tendency to vary in volume and explode when heated. The integration of this kind of compound could be very harmful for the visitors and this point gives extra importance to this important issue (http://www.breeam.org, 2010). Related with these, also there is a separate point for microbial contamination as these microorganisms could seriously affect the heaths of the visitors and occupants.

Table 2.4. Energy: 26 Possible Points (http://www.breeam.org, 2010)

Credit Description	**Point**
Reduction of CO2 Emissions	15
Sub-metering of Substantial Energy Uses	1
Sub-metering of High Energy Load and Tenancy Areas	1
External Lighting	1
Low or Zero Carbon Technologies	3
Building fabric performance and avoidance of air infiltration	1
Cold Storage	1
Lifts	2
Escalators and travelling walkways	1

This scoring category of BREEAM has an overall importance on the final scoring of the selected building as it has possible 26 points. The most important issue n this category, as can be read from the table above, is the reduction of CO2 emissions of the building starting from construction phase to management phase of the building. In addition to these, additional supplementary spaces and technologies like cold storage, lifts and escalators are also assessed in this scoring category.

Within this assessment category, reduction of CO_2 emissions has the maximum available points as it covers a vide range of issues. The reduction of CO_2

emissions could be maintained by using different techniques whether to use passive heating and cooling systems to avoid fossil fuels or use sustainable energy resources like sun or wind to power up the mechanical systems of the building (Çelik, 2009).

Most points in this assessment category cover the energy levels of the selected building. Other points like cold storage, lifts and escalators are also related with the energy use of the building and these points gave importance whether the energy needed to operate these functions came from a sustainable energy resource or not (Grace, 2000).

Table 2.5. Transport: 10 Possible Points (http://www.breeam.org, 2010)

Credit Description	**Point**
Provision of Public Transport	3
Proximity to amenities	1
Cyclist Facilities	2
Pedestrian and Cyclist Safety	1
Travel Plan	1
Maximum Car Parking Capacity	2

Transport scoring category of BREEAM shows that for sustainable development, transportation is also an important issue and this assessment system considers this issue with its possible 10 points. Through this scoring category the building is assessed with respect to public transportation, car parking, pedestrian access and travel plan. Pedestrian and cyclist safety is also an important issue for this category and have a separate credit.

Travel plan point differs from other points as this point shows the given importance to the public transportation. As a building could not survive without visitors and users, travel plans are needed to construct an accessible building in the end. Proximity of amenities points also rates and scores the building's access. Amenity in this sense refers to the distance to public transportation zones like bus, metro or car parking areas of the visitors (http://www.breeam.org, 2010).

Table 2.6. Water: 6 Possible Points (http://www.breeam.org, 2010)

Credit Description	**Point**
Water Consumption	3
Water Meter	1
Major Leak Detection	1
Sanitary Supply Shut Off	1

Since the use of water is crucial nowadays because of Global warming we face, Water scoring category of BREEAM is crucial with its possible 6 points. This category evaluates the building's performance in terms of water consumption and use. Through the table, water consumption has a great importance in this category with its possible 3 points. In addition to these, additional leak detection systems are also rewarded with a credit.

Since it is important for a sustainable building to use water in an efficient way, leaks could be very harmful. In this sense, this assessment category of BREEAM has a separate point for a building to have a leak detection system (Çelik, 2009). This leak detection system will warn the occupants that there is a leak through the system.

Sanitary is also crucial for a sustainable building as many diseases could come from the water system. The addition of a sanitary supply unit will eliminate this possibility and has an extra point within this category.

Table 2.7. Materials: 13 Possible Points (http://www.breeam.org, 2010)

Credit Description	**Point**
Materials Specification (Major Building Elements)	4
Hard Landscaping and Boundary Protection	1
Re-Use of Facade	1
Re-Use of Structure	1
Responsible Sourcing of Materials	3
Insulation	2
Designing for Robustness	1

Materials assessment category of BREEAM evaluates the performance and attributes of the materials used to construct the selected building and has possible 13 points for assessing these issues. In addition to these, re-use of facade and structure in term of materials in also an important issue for this category. Insulation details used to reduce the thermal leaks has their own credit as they have major effects on the thermal comfort of the occupants.

Through these points, recycling is crucial as there are separate points for re-use of facade and structure – especially for steel construction. The sourcing of materials is an important issue for sustainable development as the source of them designates the energy needed to extract that specific material.

Insulation has a separate point as this issue is much related with the energy performance of the building. Much of the leaking energy leaks from walls or slabs that are closely connected with the thermal insulation capacity of the materials used for those specific building elements (Grace, 2000). The use of high insulation coefficient materials for these areas has a separate point in this assessment category of BREEAM.

Table 2.8. Waste: 9 Possible Points (http://www.breeam.org, 2010)

Credit Description	**Point**
Construction Site Waste Management	4
Recycled Aggregates	1
Recyclable Waste Storage	1
Compactor / Baler	1
Composting	1
Floor Finishes	1

Waste is also an important issue in sustainable development and has its own category in BREEAM with possible 9 points. This scoring category of BREEAM evaluates the building's performance mainly in terms of waste management, especially during the construction phase of the selected building. Waste storage, composting, baler are also other issues through this category that have their own credit.

Table 2.9. Land Use & Ecology: 10 Possible Points (http://www.breeam.org, 2010)

Credit Description	Point
Reuse of Land	1
Contaminated Land	1
Ecological Value of Site and Protection of Ecological Features	1
Mitigating Ecological Impact	2
Enhancing Site Ecology	3
Long Term Impact on Biodiversity	2

This Land use and Ecology assessment category of BREEAM evaluates the side-effects of the building on its ecological surrounding and biodiversity. The reuse of land is also an important issue for contemning the biodiversity of the surrounding. Not only short term impacts of the building is considered in this scoring category but also long term impacts have their credits through this scoring category.

Through the progress of construction, the use of land is important for sustainable construction. The use and planning of contaminated land is also closely related with the health assessment category. Ecological impacts are also important and decreasing these impacts has a score in mitigating ecological impact point.

A sustainable building should also enhance its surrounding, in this sense enhancing ecology has a separate point and the effects of the building on the biodiversity are studied in long terms.

Table 2.10. Pollution: 14 Possible Points (http://www.breeam.org, 2010)

Credit Description	**Point**
Refrigerant GWP – Building Services	1
Preventing Refrigerant Leaks	2
Refrigerant GWP – Cold Storage	2
NOx emissions from heating source	3
Flood Risk	3
Minimising Watercourse Pollution	1
Reduction of Night Time Light Pollution	1
Noise Attenuation	1

Pollution is also an important issue for the sake of a sustainable society and BREEAM building assessment system has its own, separate scoring category concentrated on this issue with possible 14 points. Chemical pollutant are the main points of consideration but in addition to these, flood risk, light pollution and noise attenuation are also considered and assessed in this scoring category.

Table 2.11. Innovation: 10 Possible Points (http://www.breeam.org, 2010)

Credit Description	**Point**
Innovation	10

BREEAM also has a final scoring category named Innovation like in the LEED building assessment system. This category evaluates whether the building had any contribution of new systems to sustainable development or not. The overall weighting of this category cannot be underestimated as it has possible 10 points and can seriously affect the final assessment performance of the selected building. This scoring category forces owners and design team to think about contributing any new sustainable issues and systems while designing a building.

Looking at the categories of BREEAM gives the aspect that this building assessment system is very similar to LEED assessment system as it mostly covers the same categories. In addition, this system gives importance to current mission of the selected building that can be considered an advantage on LEED.

2.2.2. CASBEE (Japan)

CASBEE is designed by the Japan Sustainable Building Consortium to assess the buildings in Japan that also gives importance to Japanese cultural, social and political conditions. CASBEE (Comprehensive Assessment System for Building Environmental Efficiency), is a combination of assessment tools for the various phases of the building: planning, design, completion, operating and renovation (http://www.ibec.or.jp/CASBEE/english/overviewE.htm, 2010). This building assessment system is still under development. This assessment system is a complex building assessment system since its assessment methods are not concrete yet and they are open to interpretations.

CASBEE is composed of four assessment tools in terms of building construction. "CASBEE Family" is the collective name for these four tools. The included four CASBEE assessment tools are; CASBEE for Pre-design, CASBEE for New Construction, CASBEE for Existing Building and CASBEE for Renovation. Each tool is intended for a separate purpose and target user. These tools are designed to assess building uses like offices, schools, apartments, etc (http://www.ibec.or.jp/CASBEE/english/overviewE.htm, 2010).

Table 2.12. CASBEE Assessment Tools and Applicable Phases (http://www.ibec.or.jp/CASBEE/english/overviewE.htm, 2010)

Tools	**Name of the Tools**
Tool 0	CASBEE for Pre-design *(underdevelopment)*
Tool 1	CASBEE for New Construction
Tool 2	CASBEE for Existing Building
Tool 3	CASBEE for Renovation

CASBEE for Pre-design aims to assist the owner, planner and others involved at the planning (pre-design) stage of the project. It has two main roles: to assist in grasping issues such as the basic environmental impact of the project and selecting a suitable site and to evaluate the environmental performance of the project at the Pre-design stage (http://www.ibec.or.jp/CASBEE/english/overviewE.htm, 2010).

CASBEE for New Construction is a self-assessment check system that allows architects and engineers to raise the value of the building during its design process. It can also serve as a labeling tool when the building is subjected to expert third-party assessment. Remodeling and replacement construction are also evaluated under this tool, "CASBEE for New Construction" (http://www.ibec.or.jp/CASBEE/english/overviewE.htm, 2010).

CASBEE for Existing Building assessment tool targets existing building, based on operation records for at least one year after completion. (http://www.ibec.or.jp/CASBEE/english/overviewE.htm, 2010).

CASBEE for Renovation, in the same way as "CASBEE for Existing Building", targets existing buildings. It can be used to generate proposals for building operation monitoring and commissioning. (http://www.ibec.or.jp/CASBEE/english/overviewE.htm, 2010).

These four tools are used separately as implementers to the building assessment system. They are gained from the Japan Sustainable Building Consortium, considered into the process of rating the selected building. This building assessment system is still under development but since there is no other building assessment system locally used in the Asian region, its development and improvement is crucial for the future of international building assessment systems.

The following parts of this section will continue to focus more on the credit categories of CASBEE for New Construction. Different from other building assessment systems, the credits in each assessment category does not have the same single point; on the contrary each assessment category of CASBEE has the same total maximum score of 3.

Table 2.13. Noise & Acoustics
(http://www.ibec.or.jp/CASBEE/english/overviewE.htm, 2010)

Credit Description	**Point**
Noise	3
Sound Insulation	
Sound Absorption	

This scoring category of CASBEE concentrates on the mechanical performance of the selected building in terms of noise, sound insulation and sound absorption. It requires technical date from the owner or design team of the building in order to assess its performance.

Through this assessment category, sound absorption and insulation properties of the selected materials is assessed and rated in the end. Since absorption and insulation issues are close but different issues - different from other building assessment systems - CASBEE has two different issues within this assessment category.

Table 2.14. Thermal Comfort
(http://www.ibec.or.jp/CASBEE/english/overviewE.htm, 2010)

Credit Description	**Point**
Room Temperature Control	3
Humidity Control	
Type of Air Conditioning System	

Thermal comfort scoring category of CASBEE is the next assessing category. Since this building assessment system is a much more complex and technical than the other building assessment system like LEED, BREEAM and Green Star, this category also needs technical data to be obtained from the design team of the building. Since thermal comfort is crucial for indoor environmental quality of the building, it concentrates on humidity, ventilation and temperature control issues.

This assessment category, concentrates on the mechanical control units of the thermal comfort issues. Humidity, temperature and air conditioning systems are rated according to their mechanical properties and the energy need to operate these control systems.

Table 2.15. Lighting & Illumination
(http://www.ibec.or.jp/CASBEE/english/overviewE.htm, 2010)

Credit Description	**Point**
Daylighting	3
Anti-Glare Measures	
Illuminance Level	
Lighting Controllability	

Lighting and Illumination performance of a building is also very crucial for its sustainable performance and CASBEE rates this with this category. Daylighting, luminance level and the controllability of these systems is crucial in this sense.

The control of lighting systems is also an issue in this assessment category of CASBEE and also has a separate point that needs extra calculation for the performance of these systems. Besides the use of mechanical lighting, the importance on daylighting is also given in this category with a separate point.

Table 2.16. Air Quality
(http://www.ibec.or.jp/CASBEE/english/overviewE.htm, 2010)

Credit Description	**Point**
Source Control	
Ventilation	3
Operation Plan	

This category is also related with the indoor environmental quality of the building but it concentrates more on the technical and mechanical aspects of this issue.

Since these systems needs mechanical control units, the energy levels needed to operate them is very crucial. In this sense, energy source control is crucial whether the energy comes from a sustainable energy resource or not and have a separate point. Operation plan is also important as the indoor air quality should change from time to time during day and year. The planning of this issue will reduce the extra energy needed.

Table 2.17. Service Ability
(http://www.ibec.or.jp/CASBEE/english/overviewE.htm, 2010)

Credit Description	**Point**
Functionality & Usability	3
Amenity	
Maintenance Management	

This scoring category is a new category for the building assessment systems used worldwide. It tries to evaluate the performance of the building from the eyes of the occupants and needs some modifications and additions since it is crucial for a building to be occupant-friendly also. The functionality and usability credit is crucial in this sense, as is very important for the occupants of the building.

Amenity is closely related with the usability of the building and has a separate point in this assessment category of CASBEE. The amenities involve the distance to public transportation, public services, etc.

Table 2.18. Durability & Reliability
(http://www.ibec.or.jp/CASBEE/english/overviewE.htm, 2010)

Credit Description	**Point**
Earthquake Resistance	3
Service Life of Components	
Reliability	

The durability and reliability scoring category is an important scoring category for a building assessment system used in Asia. Since Japan is on an active earthquake zone, the evaluation of this aspect is crucial for the owners and design teams of the buildings. Service life of components is also another issue as it is closely related with the reliability of the building.

Reliability and service life of the materials used in the building is also crucial for this assessment category as this reliability comes with the resistance to earthquakes.

Table 2.19. Flexibility & Adaptability
(http://www.ibec.or.jp/CASBEE/english/overviewE.htm, 2010)

Credit Description	**Point**
Spatial Margin	3
Floor Load Margin	
Adaptability of Facilities	

This scoring category of CASBEE concentrates on the spatial design of the building and tries to evaluate the efficiency of the plan by means of flexibility and adaptability to other functions. Since this issue is also important for design teams, this scoring category has great importance for the owners and design teams.

The indoor functions of the building is the main issue in this category, the flexibility of the spaces and adapting specific space into a new function is the main issue for this assessment category.

Table 2.20. Outdoor Environment on Site
(http://www.ibec.or.jp/CASBEE/english/overviewE.htm, 2010)

Credit Description	**Point**
Preservation & Creation of Biotope	3
Townscape & Landscape	
Local Characteristics & Outdoor Amenity	

Similar to other building assessment tools used worldwide, CASBEE also has its category based on environment and landscape. This category tries to evaluate the landscape design of the selected building in term of its sustainable criterions. Local characteristics of the selected site and the preservation of its biotope are the main issues of this assessment category.

Table 2.21. Energy
(http://www.ibec.or.jp/CASBEE/english/overviewE.htm, 2010)

Credit Description	**Point**
Building Thermal Load	3
Natural Energy Utilization	
Efficiency in Building Service System	
Efficient Operation	

The Energy scoring category of CASBEE evaluates the sustainable performance of the building with regard to its thermal loads and natural energy utilization. In addition to these, efficiency is also an important aspect for this category as all systems related with the thermal loads of the building is analyzed technically and in the end, the system rates the efficiency of them.

The keyword of this assessment category is efficiency and energy. In this sense, the management of energy is crucial for sustainable development. The management of energy is also closely related with the thermal load of the building. The successful management of this energy will in the end create the efficiency. Efficiency in building service system and operation of these systems have separated points.

Table 2.22. Resources & Materials
(http://www.ibec.or.jp/CASBEE/english/overviewE.htm, 2010)

Credit Description	Point
Water Resources	3
Reducing Usage of Non-renewable Resources	
Avoiding the Use of Materials with Pollutant Content	

Similar to the other used building assessment system worldwide, resources and materials scoring category of CASBEE evaluates the sustainable performances of the materials used to construct the selected building. This category has also an emphasis on renewable resources and tries to direct the design teams to use more renewable resources in their designs.

Avoiding pollutant materials helps to increase the health-wellbeing properties of the selected building, that on the other hand closely related with the the visitors and occupants of it.

Table 2.23. Off-Site Environment
(http://www.ibec.or.jp/CASBEE/english/overviewE.htm, 2010)

Credit Description	**Point**
Consideration of Global Warming	3
Consideration of Local Environment	
Consideration of Surrounding Environment	

The off-site environment scoring category of CASBEE tries to evaluate the off-site sustainable criterions of the building, whether the building has an input to the sustainable development or not. Local issues are also considered in this sense as designing with respect to local neighbourhood is crucial for sustainable development.

This building assessment system uses some tools that needs some calculations (comes with the downloaded Excel file) for categorizing its assessment method. These tools are combination of several calculations – some of them concentrate on construction phase of the selected building.

Keeping in mind the simple categorization and single point assessing system of LEED, it can be said that CASBEE is a more complicated building assessment system than LEED for users and the advantage of LEED on user-friendly makes it appearance in the comparison of LEED and CASBEE as CASBEE uses complicated calculations and graphics to evaluate the performance of the selected building.

2.2.3. GreenStar (Australia)

Green Star is a new building assessment system for use in the Australian building market. It has rating tools for different phases of the building life cycle and for different building types. GreenStar assessment system was built on existing assessment systems and tools including the BREEAM and LEED system. GreenStar building assessment system covers the following categories:

Table 2.24. Green Star Categories (http://www.gbca.org.au/green-star, 2010)

Categories	**Points**
Management	12
Indoor Environmental Quality	27
Energy	29
Transport	11
Water	12
Materials	22
Land Use & Ecology	8
Emissions	16
Innovation	5

The topics covered by GreenStar building assessment system is also very similar to BREEAM and LEED as it is highly inspired by these assessment systems. A maximum of 142 points is achievable in this assessment system. The certification in this assessment system is made by various numbers of stars that indicate the level of performance. Six stars is the highest level of assessment (Kilbert, 2005). The scoring categories of Green Star Building Assessment System will be considered briefly in the following tables.

Table 2.25. Management: 12 Possible Points (http://www.gbca.org.au/green-star, 2010)

Credit Description	**Point**
Green Star Accredited Professional	2
Commissioning Clauses	2
Building Tuning	2
Independent Commissioning Agent	1
Building Users' Guide	1
Environmental Management	2
Waste Management	2

The first scoring category of Green Star building assessment system is the Management category that consists of 12 possible points. The category covers many aspects with respect to the management of the selected building. The systems covers a much more wider view in this category different than other building assessment systems and in this sense building tuning, waste management and commissioning clauses are the important credits.

The management issues are closely connected with the commissioning of accredited professional and independent agent and have their separate points in this assessment category (Civan, 2006). Management issues other than these issues are also concerned in environmental management and waste management points. Points in this assessment category of GreenStar covers the issues of ecological landscaping, re-use of land, preserving the biotope of the site, etc.

Table 2.26. Indoor Environmental Quality: 27 Possible Points (http://www.gbca.org.au/green-star, 2010)

Credit Description	**Point**
Ventilation Rates	3
Air Change Effectiveness	2
Carbon Dioxide Monitoring and Control	1
Daylight	3
Daylight Glare Control	1
High Frequency Ballasts	1
Electric Lighting Levels	1
External Views	2
Thermal Comfort	2
Individual Comfort Control	2
Hazardous Materials	1
Internal Noise Levels	2
Volatile Organic Compounds	3
Formaldehyde Minimisation	1
Mould Prevention	1
Tenant Exhaust Riser	1

The next assessment category is the Indoor Environmental Quality with available 27 points. Similar to the other categories used in different building assessment system like LEED and BREAM, this category of Green Star assesses the indoor qualities of the selected building using many aspects as assessment criteria. This category is a technical category and needs adequate technical and mechanical datas from the owner of the selected building, in order to rate the indoor environmental performance of the building. Ventilation, lighting, daylighting, thermal comfort are the main issues that this category evaluates.

This category is a combination of air quality, materials and lighting issues of the selected building. External view point is different in this sense as we do not come across in other building assessment systems. It rates the visual link between the visitors of the building to the environment and forces the selected building not to create a boundary from nature but in contrary make the visitors to create their own visual link with the environment the building surrounded (http://www.gbca.org.au/green-star, 2010).

Noise issue is an important issue as internal noise levels are calculated and rated in a separate point. The rejection of pollutant compounds or materials is also an issue in this assessment category – like the formaldehyde minimisation (a pollutant compound).

Table 2.27. Energy: 29 Possible Points (http://www.gbca.org.au/green-star, 2010)

Credit Description	**Point**
Greenhouse Gas Emissions	20
Energy Sub-metering	2
Lighting Power Density	3
Lighting Zoning	2
Peak Energy Demand Reduction	2

The energy assessing category tries to evaluate the thermal and lighting energy loads of the selected building with its possible 29 points. As understood from the table above, the main issue in this category is the assessment of greenhouse gas emissions. As this issue is also crucial for Global Warming, this credit is also very important for the assessment system. Different from other building assessment systems, this assessment category of GreenStar gives importance on greenhouse gas emissions (with available 20 points). Electrical lighting is the other important issue in this scoring category (http://www.gbca.org.au/green-star, 2010).

Similar to BREEAM, GreenStar also gives great importance to CO_2 emissions (Greenhouse gas emissions) with its possible 20 points. The sub categories of this point are the same as BREEAM building assessment system. The management of energy came on the scene with energy sub-metering point. Lighting power and zoning is also important as it also consumes energy and avoiding the extra energy is assessed in these points.

Table 2.28. Transport: 11 Possible Points (http://www.gbca.org.au/green-star, 2010)

Credit Description	**Point**
Provision of Car Parking	2
Fuel-Efficient Transport	1
Cyclist Facilities	3
Commuting Mass Transport	5

The next scoring category is the Transport category with available 11 points. Transportation and car parking are the main topics in this category of Green Star. In addition to these, as can be analyzed from the table, commuting mass transport is rewarded with 5 possible points showing that Green Star building assessment system gives great importance on public transportation.

Similar to other building assessment system, mass transportation is also an issue for GreenStar as commuting and encouraging visitors to use mass transportation has its separate point in this assessment category. In addition to these, different from other building assessment systems, GreenStar has a point for fuel efficient transport issue.

Table 2.29. Water: 12 Possible Points (http://www.gbca.org.au/green-star, 2010)

Credit Description	**Point**
Occupant Amenity Water	5
Water Meters	1
Landscape Irrigation	1
Heat Rejection Water	4
Fire System Water Consumption	1

Since water usage is crucial in sustainable design and for our sake for a sustainable society, this scoring category serves to have a sustainable water usage in the selected building. Occupant Amenity Water and Heat Rejection Water are the credits that have great weighting in this category.

Through this assessment category, occupant amenity water and heat rejection water covers most of the points. Heat rejection system is a passive system that uses water as a insulation through the building's outer core and a building uses this system gets many important points from this category.

Table 2.30. Materials: 22 Possible Points (http://www.gbca.org.au/green-star, 2010)

Credit Description	**Point**
Recycling Waste Storage	2
Building Reuse	6
Reused Materials	1
Shell and Core or Integrated Fit-out	2
Concrete	3
Steel	2
PVC Minimisation	2
Sustainable Timber	2
Design for Disassembly	1
Dematerialisation	1

The materials scoring category of Green Star evaluates the building's sustainable performance in terms of its material usage during construction with available 22 points. The evaluations of major construction materials like, concrete, steel, PVC, timber are considered in this sense.

In addition to these, this category also gives great importance on the use of recycled materials for construction. Different from other building assessment system, the credit for Design for Disassembly is crucial as this credit will in the end result in the building reuse or use of recycled materials in the management of the building.

This assessment category also gives importance on re-use of the materials as well as disassembly of them in the end of their operation lives. This process is called dematerialisation and has a separate point in this materials category of GreenStar.

Table 2.31. Land Use & Ecology: 8 Possible Points
(http://www.gbca.org.au/green-star, 2010)

Credit Description	**Point**
Topsoil	1
Reuse of Land	1
Reclaimed Contaminated Land	2
Change of Ecological Value	4

Land Use and Ecology scoring category evaluates the building's sustainable performance in terms of its construction period and excavation. In this sense the reuse of land, use of topsoil are the important credits in this category (http://www.gbca.org.au/green-star, 2010). The change of Ecological Value credit has a great importance through this scoring category as it has possible 4 points.

Change of ecological value point is what makes GreenStar different from other building assessment systems. This point assesses the environmental impacts of the building during its construction progress and rates whether the building and the design team turned these disadvantages of these impacts to an advantageous point. This in the end results in a new term, ecological value.

Table 2.32. Emissions: 16 Possible Points (http://www.gbca.org.au/green-star, 2010)

Credit Description	**Point**
Refrigerant ODP	1
Refrigerant GWP	2
Refrigerant Leaks	2
Watercourse Pollution	3
Discharge to Sewer	5
Light Pollution	1
Legionella	1
Insulant ODP	1

Emissions scoring category evaluates the building's damage to the nature in terms of watercourse pollution, light pollution and leaks. The sewer is crucial in this sense that it has 5 possible points and also important for the design of a sustainable site and landscaping.

Different from CO_2 emissions, there are also different types of emissions used in the buildings and this assessment category of GreenStar assesses and rates these emissions different to other assessment systems. Many of these emissions are pollutant and harmful for the occupants of the building. The use of these pollutant emissions are also closely related with the material selection process of the building which is also assessed in the materials assessment category (Civan, 2006).

Table 2.33. Innovation: 5 Possible Points (http://www.gbca.org.au/green-star, 2010)

Credit Description	Point
Innovative Strategies & Technologies	2
Exceeding Green Star Benchmarks	2
Environmental Design Initiatives	1

Like in LEED building assessment system, Green Star also have Innovations scoring category. Since the producers of Green Star are inspired from LEED, this category is very similar to the related category of LEED.

Since sustainable development is gaining importance all around the world, a building assessment system from a different continent like Green Star is very crucial for the future of sustainable construction. The categories and structure of this building assessment system clarifies that there is an ongoing increasing development on sustainable construction even in one of the far end of the world, Australia.

Historically, the roots of Green Star lie on LEED building assessment system. The categorization of points is similar to LEED as some additional categories are included like Transportation and Emissions categories. GreenStar building assessment system is a version of LEED building assessment system that gave some extra importance with the addition of different assessment categories.

2.3. LEED (U.S.)

After looking at the historical background of building assessment systems and analyzing some major international building assessment tools briefly, the next point will be the LEED assessment system that is the main focus of the thesis. Analyzing LEED deeply will give us a better understanding on why this system is widely used not only in U.S. but also in some other countries.

LEED is the wide-spread used building assessment standard in the U.S. and in different countries. The success of LEED is a result of a continuous development process that started in 1994 (Cole, 1999). The two most important decisions of the USGBC members developing LEED were that green buildings should be market driven and that the building owners would be in the centre in this process. A third significant decision in developing LEED was to create a consensus based process for the assessment of the selected building (Kilbert, 2005).

Most building assessment systems were produced by national building research organizations such as the Building Research Establishment (BRE) in the United Kingdom. On the other hand, LEED was produced by a cross section of the USGBC's membership with the help of a wide range of participants in the building industry (Stein, 2004).

2.3.1. History of LEED

Created in 1993, the US Green Building Council (USGBC) aims to transform the building industry to a more environmentally responsible aspect. Beginning in the mid 1990s, the USGBC undertook the development of a rating and evaluation system – LEED - to define what a green building should represent. LEED was beta-tested in 1998 and 1999 on about 50 projects in the US. In March 2000, version 2.0 of LEED was introduced as an updated, expanded version of the original LEED version 1.0. Since then, version 2.0 has had two major changes; LEED for New Construction (LEED-NC) version 2.2, that was effective since 2005 (Yudelson, 2007). With LEED version 3, online certification process is also an issue for the building assessment systems, with addition of some extra modifications on some of the credits.

Since the introduction of LEED in 2000, it has become essentially the U.S.'s national standard for commercial and industrial buildings. LEED allows a developer, architect or building owner to choose how to meet certain sustainable benchmarks. The possibility for the owner to choose a benchmark makes LEED a flexible building assessment system. Since its inception, LEED has proven to be a valuable design tool for architectural teams(Kilbert, 2005).

LEED provides four levels of certification; certified, silver, gold, and platinum. In 2003 and 2004 three projects in southern California achieved the Platinum certification rating. At the same time more than 500 projects had completed the certification process under LEED-NC (Green Building Alliance, 2004).

By the end of 2006, LEED-NC had captured about 4% to 5% of the total new building market, with nearly 4000 registered projects. At the beginning of 2007, more than 100 new projects were registered for assessment under LEED-NC (Green Building Alliance, 2004).

2.3.2. Structure of LEED

The structure of LEED is designed in a way so that each type of building is rated according to the adequate categories. Since every aspect differs from building to building- whether it is a new building or an interior space; LEED building assessment systems also differs according to the properties of these selected construction.

In this sense, LEED is not a single standard but it is a suite of building assessment standards. The best known version is the LEED for new constructions (LEED-NC) for commercial buildings. In addition to these, there are several LEED standards in various stages of use and development.

-LEED-EB: Existing Buildings

-LEED-CI: Commercial Interiors

-LEED-H: Homes

-LEED-CS: Core and Shell Projects

-LEED-ND: Neighbourhood Development (Kilbert, 2005)

In addition to these LEED standards, there are also several versions of LEED; for example a version of LEED adopted by the U.S. Army for its facilities: SPiRiT (Mendler, 2006). Green Star building assessment system explained in the previous section is also a version of LEED that clarifies LEED's simple structure and categorization also gives it the advantage of integrating new categories on it or changing the existing categories keeping in mind the new needs. This shows that LEED is such a simple and flexible building assessment system that it can be adapted or changed briefly to many other different purposes of use.

2.3.3. Credit System of LEED

Since a score is needed in this kind of assessment systems, LEED uses a single point scoring technique to rate a building's efficiency in term of sustainable construction. This point scoring of LEED makes it a better understood and simple system that can be used in every situation. These points gained from each category simply add up in the end to give the building owner a total score of the selected building.

Throughout U.S. LEED-NC is the most recent and used standard for commercial buildings. It is structured with seven prerequisites and a maximum of 69 points divided into six major categories.

Table 2.34. LEED-NC Categories (USGBC, 2010)

Category	**Points**
Sustainable Sites	14
Water Efficiency	5
Energy and Atmosphere	17
Materials and Resources	13
Indoor Environmental Quality	15
Innovation and Design Process	5
Total	**69**

The number of points available in each category was established by the developers of LEED-NC. The total of points to each category is arbitrary, which is an arguable issue for the system (Trusty, 2000). For example, that Indoor Environmental Quality (15 points maximum) is more important than Materials and Resources (13 points maximum) and three times as important as Water Efficiency (5 points maximum). In spite of its simplicity, it does an excellent job overall of taking complex information and converting it into a single number.

The total score from LEED-NC is computed from adding up the points earned in each category that results in a building rating in the end. Table 2.35 shows the certification levels of LEED. The highest level is Platinum, followed by Gold and Silver certification. Platinum LEED certified building also has a marketing advantage on other buildings and more platinum certified buildings will create a vision for people which will in the end help in developing a sustainable society.

Table 2.35. Points required for LEED-NC ratings (USGBC, 2010)

LEED-NC 2.1 Rating	**Points Required**
Platinum	52-69
Gold	39-51
Silver	33-38
Certified	26-32
No Rating	25 or less

In order to have a better understanding of this assessment system, an expanded outline version of LEED-NC is shown in the following tables. The assessment categories of LEED are analyzed through these tables and if needed the details of points will be given.

Table 2.36. Sustainable Sites: 14 Possible Points (USGBC, 2010)

Credit Description	**Point**
Soil and Erosion Control	Required
Site Selection	1
Urban Development	1
Brownfields Redevelopment	1
Alternative Transportation (Public Transportation Access)	1
Alternative Transportation (Bicycle Storage and Changing Rooms)	1
Alternative Transportation (Alternative Refuelling Stations)	1
Alternative Transportation (Parking Capacity)	1
Reduced Site Disturbance (Protect or Restore Open Space)	1
Reduced Site Disturbance (Development Footprint)	1
Stormwater Management (Rate of Quantity)	1
Stormwater Management (Treatment)	1
Landscape and Exterior Design to Reduce Heat Islands (Nonroof)	1
Landscape and Exterior Design to Reduce Heat Islands (Roof)	1
Light Pollution	1

The Sustainable Site category includes all aspects of a sustainable site and tries to score the buildings efficiency in detail starting from excavation to light pollution. This category of LEED covers almost crucial aspects of a sustainable site. The given importance to categories like alternative transportation, water management and landscape are the key sustainable factors for this assessment category.

This assessment category of LEED starts with the importance of the site of the building and the control over its site. Soil and erosion control is a must for this category while site selection has a separate point. Besides these, the development in terms of urban life has an input for this category. A separate point in urban development assesses the input of the building to its urban surroundings.

In order to have a sustainable site, transportation is also an important issue and LEED has separate points for public transportation, refuelling stations, bicycle storage, parking capacity issues. As the other building assessment systems have, LEED also gave importance to public transportation and encourages design teams to consider this issue in their design process.

Site impacts of the building are also important as this category has two separate points for reduced site disturbance. Reducing heat islands is the next issue in this category, as most of the unwanted heat comes from roof, the integration of systems to reduce heat islands are assessed with separate points for roof and nonroof. Lighting levels and light pollution is the last issue for this category of LEED for the sake of a sustainably developed site.

Table 2.37. Water Efficiency: 5 Possible Points (USGBC, 2010)

Credit Description	**Point**
Water-Efficient Landscaping (Reduce by 50%)	1
Water-Efficient Landscaping (No potable use of no irrigation)	1
Innovative Wastewater Technology	1
Water Use Reduction (20% reduction)	1
Water Use Reduction (30% reduction)	1

Since water efficiency is also crucial for a sustainable building, LEED covers this issue in a separate category. Looking at the credits it can easily be seen that even landscaping is an issue to be considered while planning a water efficient structure. Just this aspect can be commented that LEED building assessment system tries to score a building in a much more detailed and wider view different from other international building assessment systems.

There are several systems for wastewater technologies in the market and a separate point on this issue gathers informations from the design team of the building and rates the efficiency and sustainability of the selected wastewater system.

Since landscaping is an important issue and irrigation is a problem for design teams that look for sustainability, two separate points are placed in this assessment category on water-efficient landscaping followed by water use reduction points.

Table 2.38. Energy and Atmosphere: 17 Possible Points (USGBC, 2010)

Credit Description	**Point**
Fundamental Building Systems Commissioning	Required
Minimum Energy Performance	Required
CFC Reduction in HVAC&R Equipment	Required
Optimize Energy Performance (20% new / 10% existing)	2
Optimize Energy Performance (30% new / 20% existing)	2
Optimize Energy Performance (40% new / 30% existing)	2
Optimize Energy Performance (50% new / 40% existing)	2
Optimize Energy Performance (60% new / 50% existing)	2
Renewable Energy (5%)	1
Renewable Energy (10%)	1
Renewable Energy (20%)	1
Additional Commissioning	1
Ozone Depletion	1
Measurement and Verification	1
Green Power	1

Energy and Atmosphere category is the next important assessment category within the structure of LEED. The focal point of this category is the renewable energy points as optimizing energy performance is also crucial for the assessment system.

In this assessment category, optimizing energy performance are the key points if a design team wants to score in this category. The management of energy is involved in these points as a comparison between new and existing energy levels are also to be made with the help of these points. The level of renewable energy the selected building uses also has separate points starting from a minimum of 5% to 20%.

Table 2.39. Materials and Resources: 13 Possible Points (USGBC, 2010)

Credit Description	**Point**
Storage and Collection of Recyclables	Required
Building Reuse (Maintain 75% of Existing Shell)	1
Building Reuse (Maintain 100% of Shell)	1
Building Reuse (Maintain 100% of Shell and 50% Nonshell)	1
Construction Waste Management (Divert 50%)	1
Construction Waste Management (Divert 75%)	1
Resource Reuse (Specify 5%)	1
Resource Reuse (Specify 10%)	1
Recycled Content (Specify 25%)	1
Recycled Content (Specify 50%)	1
Local/Regional Materials (20% manufactured locally)	1
Local/Regional Materials (of 20% above, 50% harvested locally)	1
Rapidly Renewable Materials	1
Certified Wood	1

It can be easily determined that the emphasis on Materials and Resources category of LEED is given on the reuse and recycling of materials used in the building. The points try to force the owners or the companies to use more recycled and renewable materials in constructing their buildings as using local material also has a separate point that gives the owner a different point of view.

Building reuse, construction waste management, resource reuse and recycled content are the primary issues in this assessment category. The main idea lies is the concept of reuse and recycling as it is an important issue for sustainable materials and resources.

Local regional material points encourage design teams to look for available materials as material transportation will also a waste of time and energy. The certification of the wood used in the construction process of the building is also rewarded with separate point in this category.

Table 2.40. Indoor Environmental Quality: 15 Possible Points (USGBC, 2010)

Credit Description	**Point**
Minimum IAQ Performance	Required
Environmental Tobacco Smoke Control	Required
Carbon Dioxide Monitoring	1
Increase Ventilation Effectiveness	1
Construction IAQ Management Plan (During Construction)	1
Construction IAQ Management Plan (Before Construction)	1
Low-Emitting Materials (Adhesives)	1
Low-Emitting Materials (Paints)	1
Low-Emitting Materials (Carpets)	1
Low-Emitting Materials	1
Indoor Chemical and Pollutant Control	1
Controllability of Systems (Perimeter)	1
Controllability of Systems (Non-perimeter)	1
Thermal Comfort (Comply with ASHRAE 55-1992)	1
Thermal Comfort (Permanent Monitoring Systems)	1
Daylight and Views (Daylight 75% or Spaces)	1
Daylight and Views (Daylight 90% or Spaces)	1

Indoor Environmental Quality assessment category covers the crucial aspects of a sustainable indoor design and mostly focused on the passive systems like passive heating and cooling systems, daylighting systems and thermal mass of the building. As well as these, material selection is crucial for this category.

This assessment category mainly concentrates on the materials used indoor, their properties in terms of pollutant and the controllability of the indoor environmental ventilation systems like thermal comfort systems.

In addition to these aspects, this category of LEED also gives importance to daylighting as it rates the daylight penetrates to interior spaces and has separate points.

Table 2.41. Innovation and Design Process: 5 Possible Points (USGBC, 2010)

Credit Description	**Point**
Innovation in Design (Specific Title)	1
Innovation in Design (Specific Title)	1
Innovation in Design (Specific Title)	1
Innovation in Design (Specific Title)	1
LEED Accredited Professional	1

This last category of LEED building assessment system score a buildings future directions, whether it has a role in the future of sustainable design or not. The four credits based in innovation in design in this assessment category, are specifically defined by the owner and design team of the selected building. The design team gave the needed data to the certification council to show their new innovative system (whether a technical standard, system or a spatial property), and the council evaluates and rates these data in this assessment category of LEED.

LEED Accredited Professional point is a different aspect as it tries to direct construction companies to have a professional of LEED as this systems needs some major documentation of the building (its materials, management, etc…). And having a professional just for LEED accreditation will help to increase the importance of sustainable construction worldwide.

CHAPTER 3

COMPARISONS BETWEEN LEED AND OTHER BUILDING ASSESSMENT STSYEMS

This chapter of the thesis will focus on the comparisons of the building assessments systems described in the previous chapter. The comparisons will be realized among BREEAM, CASBEE, GreenStar and LEED building assessment systems. These assessment systems will be compared with respect to their general properties, assessment categories and evaluation of their assessment (whether the system uses a single point scoring system or not). In the end, with the data gained from this comparisons and analysis of major differences between these four building assessment systems and the advantages of LEED assessment system on other systems will be clarified.

These assessment tools have helped to provide a way of communicating with building owners, managers, architects and others interested in the built environment. LEED, BREEAM, CASBEE and GreenStar building assessment systems are intended to be used to assess entire buildings and to assign a score or rating. By comparing these building assessment systems with each other will give a better understanding on the concept of building assessment systems and the advantages and disadvantages of each system with respect to the other assessment systems. In the sub-chapter 3.1, the comparison will focus on the general properties of the assessment systems like their origin, versions, etc. Sub-chapter 3.2 will be about the assessment categories of each assessment systems. In this sub-chapter, the categories of each system will be defined and analyzed whether it has an advantage on other systems or not. Sub-chapter 3.3 is about the scoring system of these four systems, whether a single point scoring system is used or a different approach. In the end, sub-chapter 3.4 will combine the comparisons in order to draw conclusions.

3.1. Comparisons on General Properties

The first sub-section of the chapter will compare BREEAM, CASBEE, GreenStar and LEED building assessment systems with respect to their general properties. These general properties consist of: its date, origin, whether the system is internationally used or not and for which building types the assessment system could be applied.

The first assessment system to be analyzed is the BREEAM building assessment system. BREEAM is the earliest example of building assessment systems with its starting date, 1990. The system is used by United Kingdom. But in addition to its local use, this building assessment tool is also an international system that can be adapted to different countries. BREEAM system assesses many building types as it has many sub-categories in its structure. This building assessment system can be used for other buildings, courts, sustainable homes, ecohomes, healthcare, industrial, multi-residential, prisons, offices, retail, education, communities and domestic refurbishment.

As can be understood from these versions of BREEAM, this building assessment system covers a very wide range of building types starting from a single storey building to a much more complex urban refurbishment (Civan, 2006). But this wide range on categories also makes this system complex as the users could be confused in these versions of BREEAM. But this complexity in the versions of BREEAM also makes it a more complete building assessment system for a sustainable society. Compared with the LEED building assessment system, BREEAM is the oldest example on the field of building assessment systems. The variety of version of BREEAM is more than the LEED system has – in number. This is an advantage of BREEAM on LEED, as it covers a broader view in this sense. LEED, on the other hand, has separate versions for primary building types like new construction, interiors, shell.

CASBEE is the next building assessment system to be considered. Different from BREEAM, CASBEE building system is a very new assessment system started to be used in 2004. It is not an international assessment system and used as a local system in Japan. CASBEE assessment system also has some different versions for different building types: pre-design, new construction, existing building and renovation. As this system is a new assessment system in the history of building assessment system, it still needs some developments and practical use to show its potential in building assessment. The versions of CASBEE cover mainly the primary building types different from the wide range of BREEAM. Also when compared with the LEED assessment system, CASBEE lacks in the versions as it is not adequate to cover just a few building types.

GreenStar is also a new building assessment system with its starting date 2003, used locally by the Australian building market. This building assessment system is highly inspired by BREEAM and LEED assessment system and build upon these systems. Since this system is some kind of a combination of BREEAM and LEED systems, it mainly focuses on the building types of each assessment system like new construction, commercial, site, etc. But again the versions of GreenStar does not cover the same range of BREEAM but still it covers a much more wide range of building types than CASBEE assessment system, which makes GreenStar an in-between building assessment system between BREEAM and LEED in terms of target building types. In this sense the variety of building types is very similar to these two building assessment systems and covers an adequate sustainable view for the development of sustainable design.

The last building assessment system to be analyzed with respect to its general properties is the LEED building assessment system. LEED assessment system emerged in 1998 and is being used by the U.S. This assessment system inspired many other building assessment systems (like GreenStar building assessment system) but it is still a local building assessment system. Other countries analyze this system and create their own version of building assessment system. LEED also covers many other different building types. The versions of LEED are: existing buildings, commercial interiors, homes, core and shell projects and neighbourhood development. The building types that LEED building assessment system covers are the main building types like existing buildings and homes. Again, this assessment system does not cover a wide range like BREEAM assessment system covers (BREEAM covers building types like prisons, eco-homes, hospitals, retail, etc).

Some conclusions can be drawn from these analyses. Thorough these four assessment systems; BREEAM is the oldest and most experienced system followed by LEED. CASBEE and GreenStar can be seen as their versions with respect to BREEAM and LEED but they also do a great job in assessing building for their local use and in time CASBEE and GreenStar will turn into more complete assessment systems.

CASBEE and GreenStar building assessment systems are just used locally in Japan and Australia which makes these systems very essential for their surrounding local region, while BREEAM also has a separate version concentrated on international use. LEED is said to be a local building assessment system used in U.S. but since the building market in U.S. is huge and this market draws the way to sustainable development, LEED building assessment system is getting great importance and it influences many other sustainable design councils to create their own building assessment system.

With respect to their concentration on building types, BREEAM has a more wide range of view as its versions of assessment start from single storey residential ranges to huge urban refurbishments. LEED is the following assessment system in this sense as it covers major building types like existing buildings and homes. Different from the complexity of BREEAM in terms of its versions for each building types, the concentration on major building types gives LEED building assessment system the advantage of simplicity on BREEAM building assessment system. As GreenStar is an international version of LEED and BREEAM, it again covers the building types as the LEED system covers. In this sense the same things can be said for GreenStar. The building assessment system that has more disadvantages in this sense is CASBEE as it covers a narrower range with regard to building types.

To sum up, BREEAM is the oldest building assessment system among these four assessment systems and concentrates on many different building types on assessment which is acceptable for the sustainable development of the society. But this complexity of BREEAM makes LEED as the most user-friendly and simple building assessment system among these systems where CASBEE and GreenStar are out of this field.

3.2. Comparisons on Assessment Categories

This section will focus on the comparisons of these four building assessment systems with respect to their assessment categories. These assessment categories will clarify the main structures of each assessment systems.

Starting from BREEAM assessment system, the assessment categories of this system are: management, health & wellbeing, energy, transport, water, materials, waste, land use & ecology, pollution and innovation. As can be understood from these assessment categories, BREEAM covers many topics with respect to sustainable development. Through these categories energy category has the highest points followed by other categories with similar points as the water category has the lowest points. Compared to the assessment categories of LEED assessment system, BREEAM has more categories that concentrate both on the social and technical aspects of sustainable design. But this also creates some disadvantages as more categories mean more data to be collected which in the end could create a complexity for the design team.

The next building assessment system, CASBEE has also many assessment categories that are: noise & acoustics, thermal comfort, lighting & illumination, air quality, service ability, durability & reliability, flexibility & adaptability, outdoor environment on site, energy, resource & materials and off-site environment. Different from other building assessment systems, the assessment categories of CASBEE mainly concentrates on technical issues with respect to sustainable development. Many of these assessment categories need complex and detailed calculations as this technical property is the main issue of CASBEE system which makes it a complex and difficult to understand for the users of it.

The interesting part of this assessment system is that, each assessment category has the same maximum weighting – 3 points. Different from LEED, CASBEE has more assessment categories concentrated on more technical aspects of sustainable development.

GreenStar building assessment system is the next system to be analyzed in this sense. As this assessment system is a version of LEED system, the assessment categories of it is very similar to LEED. The assessment categories of GreenStar consist of: management, indoor environmental quality, energy, transport, water, materials, land use & ecology, emissions and innovations. Through these categories indoor environmental quality, energy and materials have the highest available points as land use & ecology and innovations categories has the lowest available points. The innovations assessment category is crucial for this system as this category assesses whether the assessed building made an impact on sustainable development or not and this category is crucial for the development of sustainable society. The assessment categories of GreenStar cover both technical and social aspects different from the more technical based categorization of CASBEE, similar to BREEAM and LEED building assessment systems.

The last building assessment system to be analyzed with respect to its assessment categories is the LEED building assessment system. The assessment categories of LEED are as follows: sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality and innovation and design process.

The categories sustainable sites, energy and atmosphere, materials and resources and indoor environmental quality have almost the same maximum available points within this assessment system, while water efficiency and innovation and design process categories has the same and the lowest maximum available points within the structure of LEED. The last assessment category of innovation and design process category is also crucial for the development of sustainable development as this category assesses the building's input to the world of sustainable development. This category can also be found in GreenStar building assessment system as it is an international version of LEED.

Some conclusions can be made by using the assessment categories of these four building assessment systems. Through these systems, BREEAM has the most assessment category in number each concentrating on different aspects of sustainable development and design. But the high number of these categories creates a disadvantage for the BREEAM building assessment system as these numbers also affect the asked data from the owners which will in the end create extra expenses. The number of assessment categories of BREEAM also creates a loss of attention, in this sense BREEAM is away from being a user-friendly building assessment system. The weighting of each assessment category also gives the owner a chance to select two or more categories and gain all of their points from there to receive an excellent certification in the end. The weighting of some of these categories are also open to discussion.

The assessment categorization of CASBEE is highly concentrated on technical and mechanical issues of sustainable design. The assessment categories of it require complicated calculations and graphical representations that could dissuade the users from the beginning of the assessment process.

The categorization of GreenStar is very similar to LEED building assessment system but in addition to that, it also includes some aspects from BREEAM assessment system. Different from LEED, GreenStar does not have an equally distributed point system for its assessment categories. But it is much more user friendly with regard to CASBEE building assessment system.

On the other hand, LEED almost gave equal importance on each of its categories with respect to available points which is an advantage on other building assessment systems. The assessment categories of LEED are adequate in number and the captions of the categories cover all aspects of sustainable design. The advantage of having the same available maximum points in each category does not allow owners to just select some categories and gain all points from their selected categories. In this sense, LEED forces owners of the buildings to address every category within the structure of it, which is a huge advantage on other building assessment systems with respect to the development of sustainable design.

To sum up, when the idea is the simplicity and user-friendliness of the building assessment system, LEED is the leading system with its adequate but complete assessment categorization and equally distributed points among each assessment category. In this sense, CASBEE is the most complex system as it requires sophisticated technical calculations and graphics to in the end turns them into a single certification. GreenStar and BREEAM have more categories than LEED which, in the end, makes them complex for the users of these building assessment systems. The scoring weightings of the categories of BREEAM and GreenStar are also not equally distributed like LEED.

3.3. Comparisons on Scoring Systems

This section will focus on the point systems of the selected four building assessment systems. The point structures of these systems will be discussed and compared in the end.

Starting from the BREEAM building assessment system; this system as many other building assessment systems use a single point system for each credit in the related assessment category. Since the weightings of the assessment categories changes, the points gained from the categories that has high available points is very crucial for the owner to get an accredited certification from BREEAM. The unequally distributed points between assessment categories are one of the major disadvantages of BREEAM when compared with the scoring systems of other systems.

CASBEE, different from other building assessment systems, uses a different approach to this single point scoring system. Each category of CASBEE has the same total 3 available maximum points and the point of each credit related to its assessment category is calculated by dividing the maximum available point to the number of credits in the selected assessment category. Since each assessment category has the same point – the points are equally distributed among categories – the weighting of the categories are the same which is a crucial thing in the history of building assessment systems. But this point distribution advantage is nearly worthless as the categories of CASBEE are very complex in the technical calculation sense and is not a user-friendly building assessment system.

GreenStar and LEED building assessment systems also use a single point for each credit in their assessment categories. Similar to BREEAM, the weighting of each category changes in this system.

To sum up, BREEAM, GreenStar and LEED use single point for each credit in the categories while CASBEE uses a completely different approach. CASBEE's approach promises development of building assessment systems in terms of scoring. This new point system of CASBEE seems complex to many new users of building assessment systems as they are accustomed to use systems like BREEAM and LEED for many years that uses single point scoring system. In this sense if the main idea of the building assessment systems is to be both simple and user-friendly, single point system used by BREEAM, GreenStar and LEED is much more applicable than CASBEE's scoring system.

3.4. Conclusions

Several conclusions can be drawn from these comparisons. A system that rates a building on all criterions presents a more complete building assessment system. When users can choose the criteria to be included in the scoring, negative aspects of the building are not reflected in the overall score. The disadvantage of this approach is that, a more complete approach costs higher and more effort is required for gathering the required data (Retzlaff, 2009). In this sense, BREEAM has the highest number of assessment categories which requires extra expense. LEED has adequate assessment categories and these categories cover aspects of sustainable design, which makes LEED building assessment system a much more widespread assessment system among BREEAM, CASBEE and GreenStar.

LEED is attractive to users with its simple check-list system and can serve several purposes including design assistance; but it can not be modified as easily to reflect regional differences and other concerns (Trusty, 2000). Most building assessment systems require training programmes for their assessors. LEED building assessment system depends on the design team to gather required information and to submit their documentation to the rating organization.

These comparisons give us a better understanding of the properties and structures of different building assessment systems. Each system has advantages and disadvantages on one another assessment system but LEED is the system that has more advantages on other building assessment systems with its simplicity, flexibility and ease of use.

Figure 3.1 shows the primary issues that the comparisons concentrated on. The methodology of the comparisons are divided into three sub-categories which are; general informations, assessment categories and scoring systems. The comparisons were made according to these sub-categories. In the end, as can be read from the figure, BREEAM is the oldest building assessment systems among other systems while GreenStar and CASBEE are the most recent ones. LEED is located in the middle of these systems in this sense as a combination of new – inspiring – and old topics on building assessment systems. Through these systems, BREEAM and LEED can be applied to different countries while CASBEE and GreenStar can only be used in their local building markets. The versions of these building assessment systems also vary. BREEAM and GreenStar have the highest number of versions that could easy distract the attention of the owners while LEED was structured easily to assess major building types.

The assessment categories of each system differ as it is difficult to find common assessment categories. CASBEE has the highest number of assessment categories that concentrated on more technical issues with respect to sustainable design. BREEAM and GreenStar systems follow CASBEE in this sense that they have significant number of assessment categories, too. At the first glimpse, the number of assessment categories of LEED could draw a conclusion that LEED is not sufficient enough to assess the selected building's performance in terms of sustainable design; but when analyzed deeply by looking at all the separate assessment categories and credits of the four building assessment systems, it is seen that the assessment categories of LEED is a combination of the major sustainable criterions that is represented in six assessment categories. The assessment categories of LEED are summarized versions of all the assessment categories of the other building assessment systems mentioned in the thesis.

In terms of their scoring systems, BREEAM, GreenStar and LEED use the single point scoring system where every credit has its constant score; but on the other hand CASBEE uses a totally different version where all assessment categories have maximum score of three and the credits vary according to this. This new scoring system promises development for the future but for now, it is a complex version of scoring a building's performance where users are familiar with single scoring system.

	General Informations				Assessment Categories	Scoring Systems	
	Date	Country	Use	Versions		Single Point	Other
BREEAM	1990	UK	can be applied to diferent countries	Multi-residential Courts Ecohomes Healthcare Industrial International Prisons Offices Retail Education Communities, Domestic Refurb.	Management Health & Wellbeing Energy Transport Water Materials Waste Land Use & Ecology Pollution Innovation	✓	
CASBEE	2004	Japan	only for local use	Pre-design New Construction Existing Building Renovation	Noise & Acoustics Thermal Comfort Lighting & Illumination Air Quality Service Ability Durability & Reliability Flexibility & Adaptability Outdoor Environment on Site Energy Resources & Materials Off-Site Environment		✓
GreenStar	2003	Australia	only for local use	Education Healthcare Industrial Multi-unit Residential Office Retail Convention Centre Custom Public Building	Management Indoor Environmental Quality Energy Transport Water Materials Land Use & Ecology Emissions Innovation	✓	
LEED	1998	U.S.	can be applied to diferent countries	New Construction Existing Buildings Commercial Interiors Homes Core and Shell Projects Neighbourhood Development	Sustainable Sites Water Efficiency Energy and Atmosphere Materials and Resources Indoor Environmental Quality Innovation and Design Process	✓	

Figure 3.1. Comparisons of Building Assessment Systems

The comparisons draw why LEED is the widespread used building assessment system used worldwide. Because of its simple structure, clearly divided categories, equally distributed points among assessment categories LEED is a simple and flexible building assessment system and these properties of LEED makes it a wide-spread building assessment system around the World. Some categories (like Management in BREEAM) does not appear separately in LEED but the crucial aspects in terms of sustainable development in included in separate points in different assessment categories of LEED building assessment systems. The following chapter will focus on analyzing these findings on the case study of California Academy of Sciences by Renzo Piano.

CHAPTER 4

CASE STUDY: CALIFORNIA ACADEMY OF SCIENCES

After having informations about LEED, BREEAM, CASBEE and GreenStar building assessment systems and comparing them according to their general properties, assessment categories and scoring systems; this chapter will focus on the selected case study: California Academy of Sciences. The chapter will start from the general information about California Academy of Sciences and will be followed by the LEED scoring of the building.

After having a better understanding of the selected building, in order to clarify the advantages of LEED on other building assessment systems, the building will also be rated by using BREEAM, CASBEE and GreenStar building assessment systems.

California Academy of Sciences by Renzo Piano is rated by LEED and gained LEED Platinum certification which makes it a socially trusted building as USGBC designed LEED to be so. Its scoring sheet gained from USGBC is accessible which makes it a helpful case study in terms of its accessibility that the LEED scoring sheet of the building is accessed. Looking deeply on the scoring performance of California Academy of Sciences will give a better understanding on the scoring fundamentals of LEED assessment system.

Assessing and gaining a certification from a building assessment system also gives the building a marketing input. In this case, California Academy of Sciences gained the highest level of certification from LEED assessment system – Platinum certification - which also improves the publicity of the building among its surroundings. It is a high-profile project and since the baseline of LEED mostly focuses on energy and mechanical & technical performance of the building, the selected case study will clarify the baseline of LEED building assessment system. The LEED certification of a building like California Academy of Sciences is also crucial for the public awareness on the building assessment systems in the society. People will also look at its LEED certification and perceive the importance of building assessment systems in our developing new sustainable environment.

When looked deeply on the scoring performance of the building, it can easily be seen that the building almost got every point from the categories Sustainable Site, Indoor Environmental Quality and Innovation & Design Process; which has a great importance on sustainable development. It is a recent project made by a Pritzker winner architect, Renzo Piano, which will also give a better understanding of the contributions made by architects for the sake of a sustainable environment.

4.1. General Information

California Academy of Sciences or The Osher Living Roof is finished in 2007 and designed by Renzo Piano. The owner of the Project is California Academy of Sciences. The Project is located in San Francisco, CA, USA. The building type of the Project is educational. It has a total size of 19.7000 sq.ft. The Project has a custom and extensive green roof with a slope of 65%. It is a public building and can be accessed easily with its alternative transportation routes (Renzo Piano Building Workshop, http://rpbw.r.ui-pro.com, 2010).

The Designers/Manufacturers consists of:

Greenroof Consultant: Rana Creek Living Architecture

Ecological Consultant: Paul Kephart, Rana Creek

Architect: Renzo Piano Building Workshop

Engineering and Sustainability Consulting: ARUP

Landscape Architecture: SWA Group

General Contractor: Webcor Builders

Waterproofing: American Hydrotech

Building Envelope Design Consultant - Waterproofing Design: Simpson Gumpertz & Heger

Senior Curator of Botany: Frank Almeda, California Academy of Sciences

The aerial view (Figure 4.1) gives us an idea of its surroundings as it is located in a green landscape. It is one of the reasons why the design team chose to design a green roof on top. The green roof when looked from a bird eye view, gives us the idea of continuation of the landscape which makes the building harmonious with its surroundings.

Figure 4.1. Aerial view of California Academy of Sciences (http://www.logicaenergetica.it/wp-content/uploads/california-academy-of-sciences.jpg, July 2010)

The basement of the building is preserved to technical and mechanical rooms generally (Figure 4.2). The collection part of Botany area, Steinhart Aquarium's technical and mechanical support units, Mammal collection depots and the crucial parts for two huge sphere domes inside the building – Planetarium and Rainforest domes – are involved in this level of the building. In addition to these, the kitchen part is also located in this level to service the café area in the ground floor plan.

Utility plant area is located also in this level but not integrated directly with the building, this utility plant is located in the northwest direction of the building to function properly and efficiently.

The building is designed to consist of a single level structure where the ground floor plan is crucial for the building (Figure 4.3). In this level of California Academy of Sciences, the main entrances to aquarium, planetarium and rainforest is located. The exhibition halls attached to two domes is located in this level while a "piazza" is connecting these two domes – planetarium and rainforest. The administration and laboratories are also in this level. The south section of the plan is preserved for a pavilion and African hall.

The upper floor plan (Figure 4.4) is preserved for the depots of collections. The two giant planetarium and rainforest domes also continue in this level of the plan. African hall and pavilion has also its levels in this floor plan.

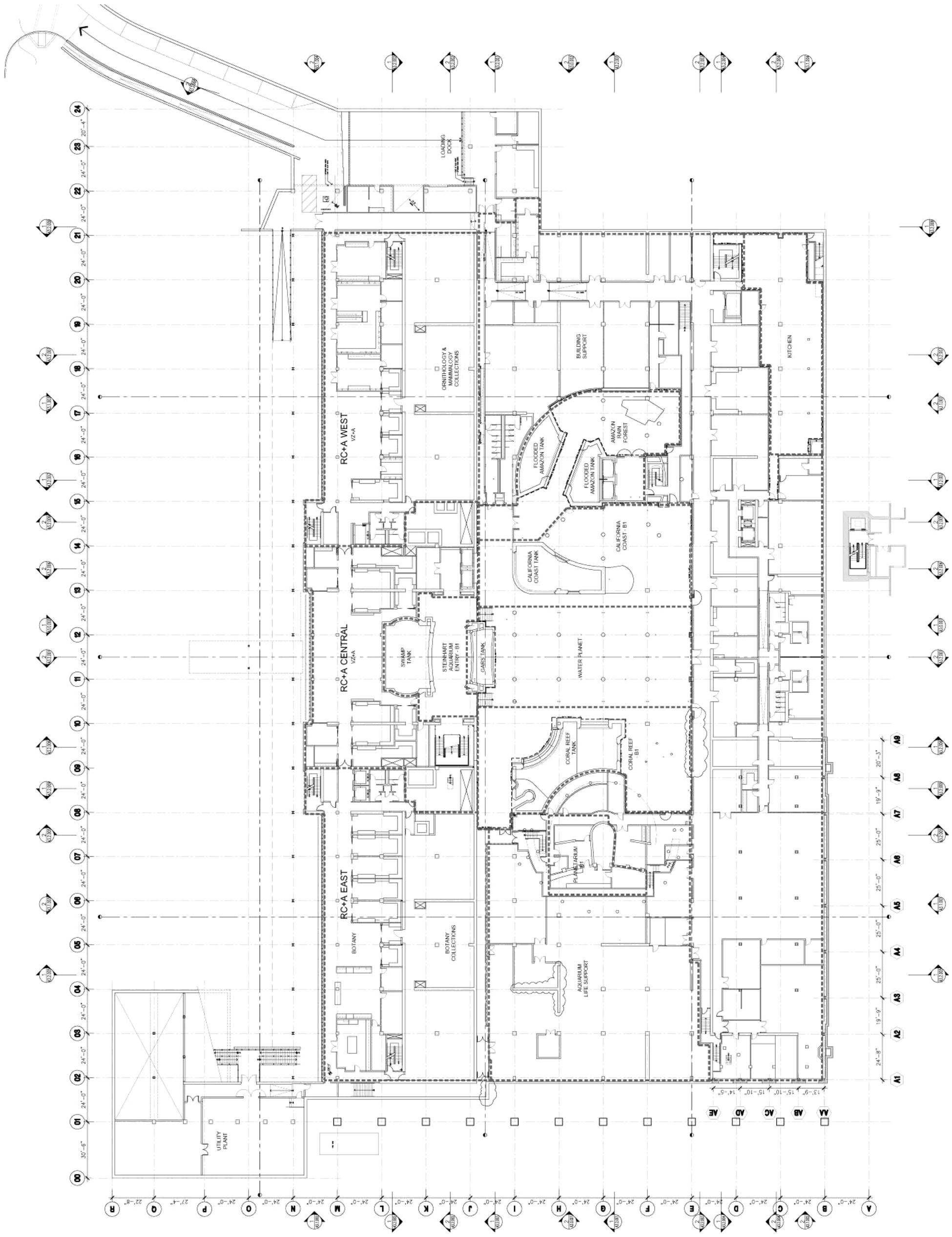

Figure 4.2. Basement Floor Plan, California Academy of Sciences
(by courtesy of Renzo Piano Building Workshop)

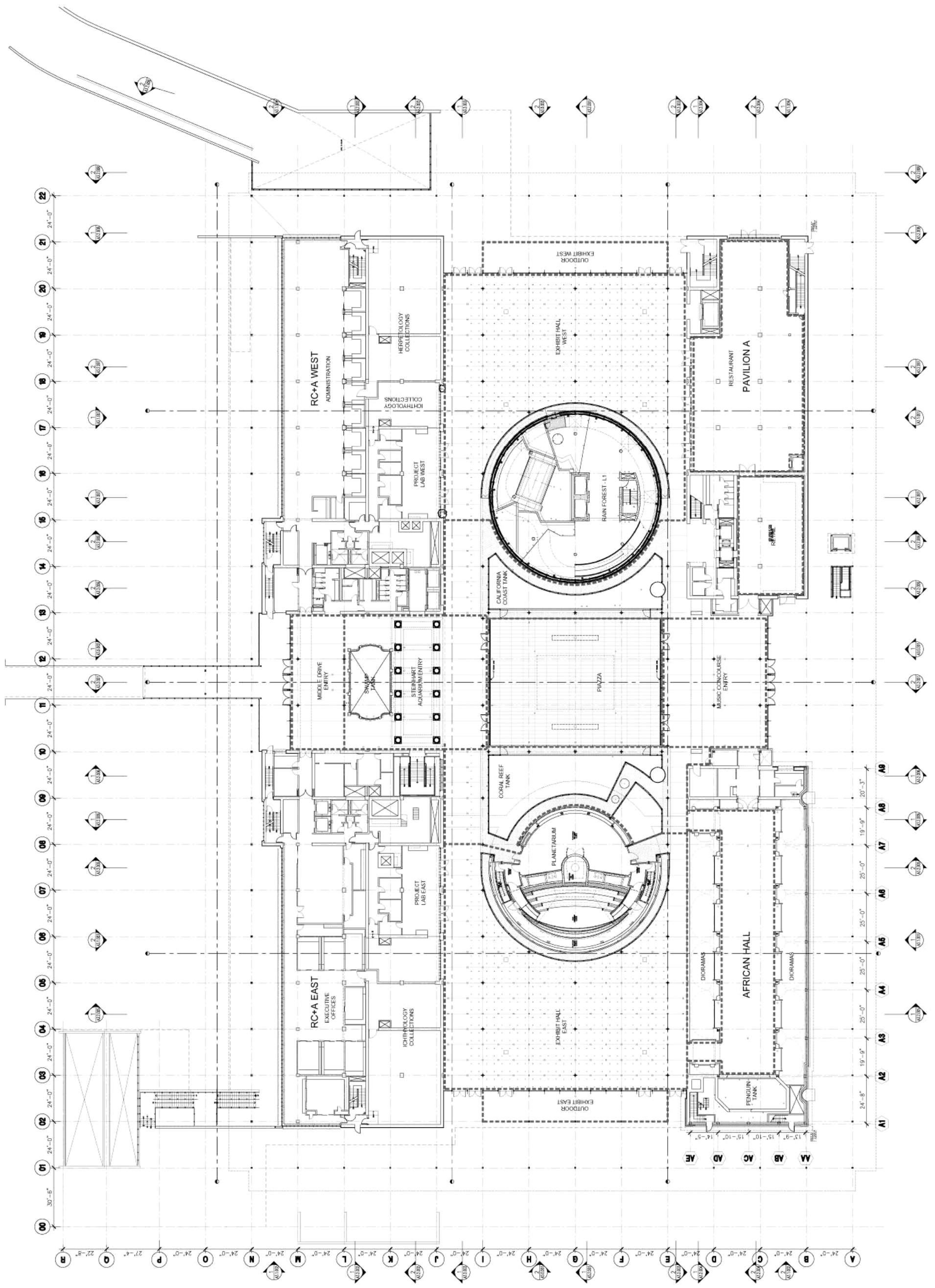

Figure 4.3. Ground Floor Plan, California Academy of Sciences
(by courtesy of Renzo Piano Building Workshop)

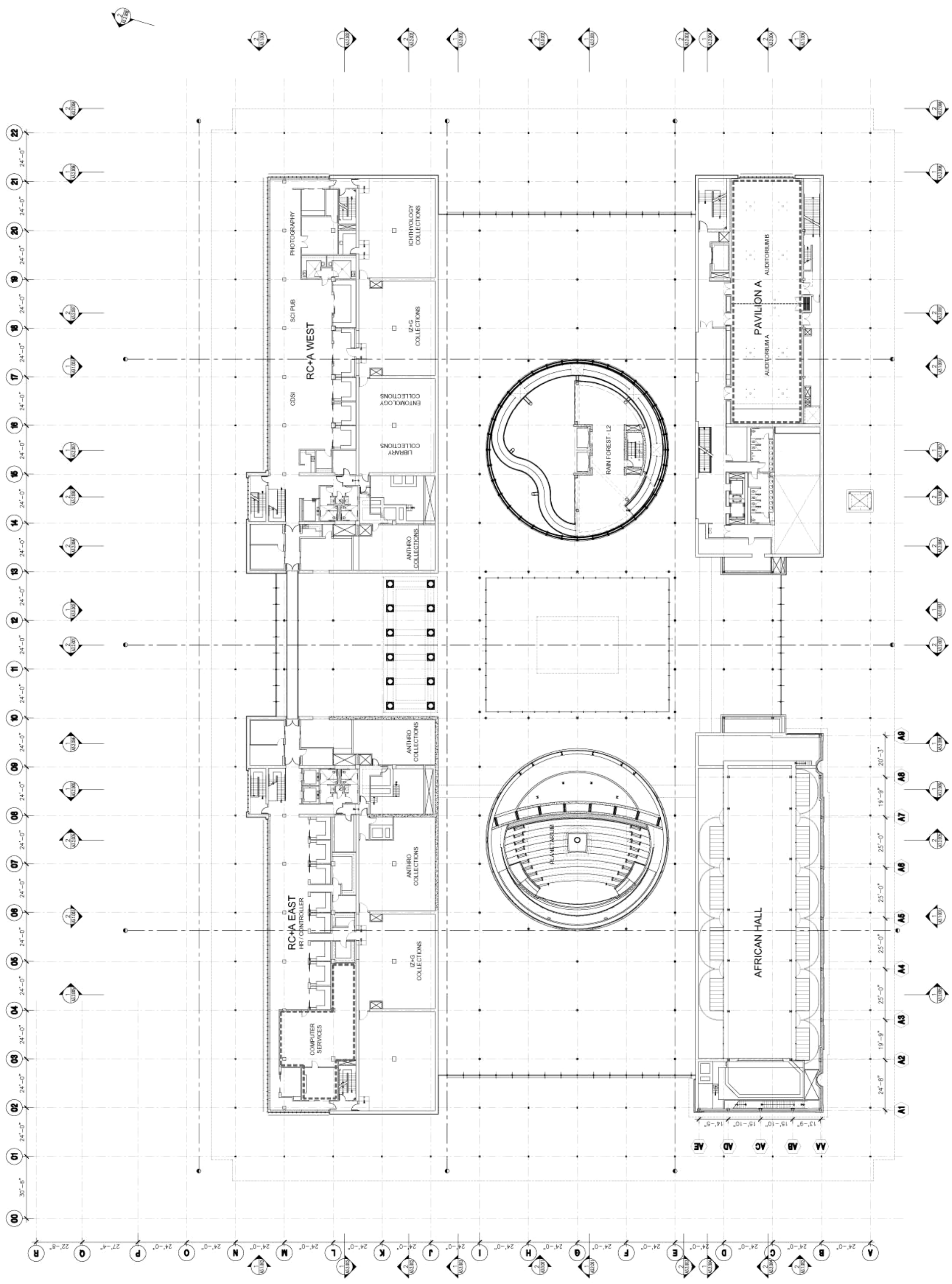

Figure 4.4. Upper Floor Plan, California Academy of Sciences
(by courtesy of Renzo Piano Building Workshop)

By looking at the section of the building (Figure 4.6), it is very clear that the building is also using passive systems like passive heating and cooling of the interior space by creating some openings on the green roof and ventilating them adequately. Rainwater collection is also an issue that is considered while designing the building which has also a scoring in the LEED assessment system.

By looking at the elevation (Figure 4.5) and section of California Academy of Sciences, it can be asserted that the building uses many passive systems in terms of sustainable design. The density of trees perceived from elevation helps to restore adjacent park and designates a natural shadow for car parking area where no additional structure is needs for this function. The green roof that the design team gave great importance also creates an extra insulating layer for the building. The geometry of the roof is also important in terms of ventilation. The roof is designed by the design team in a way that the cool wind is penetrated into the building efficiently by using Venturi effect.

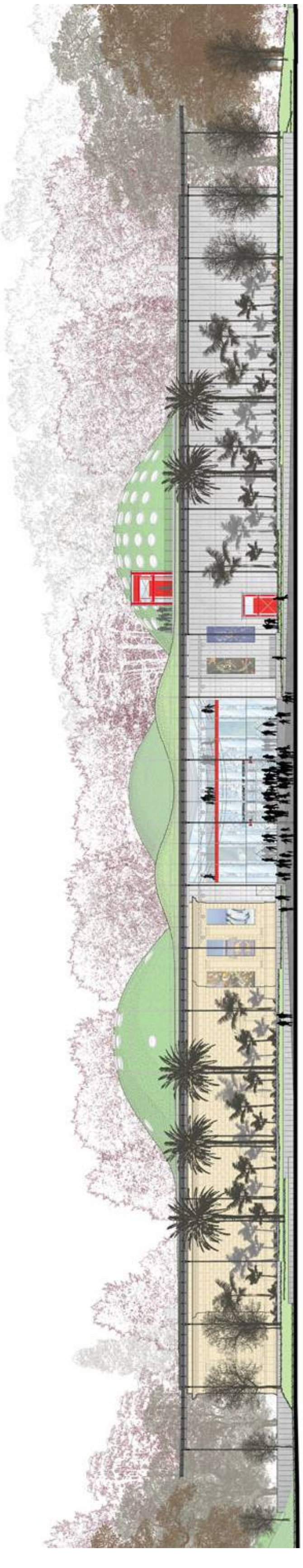

Figure 4.5. Elevation, California Academy of Sciences (http://www.thegridbroker.com/storage/04_cutaway_view.jpg?__SQUARESPACE_CACHEVERSION=1223103349292, July 2010)

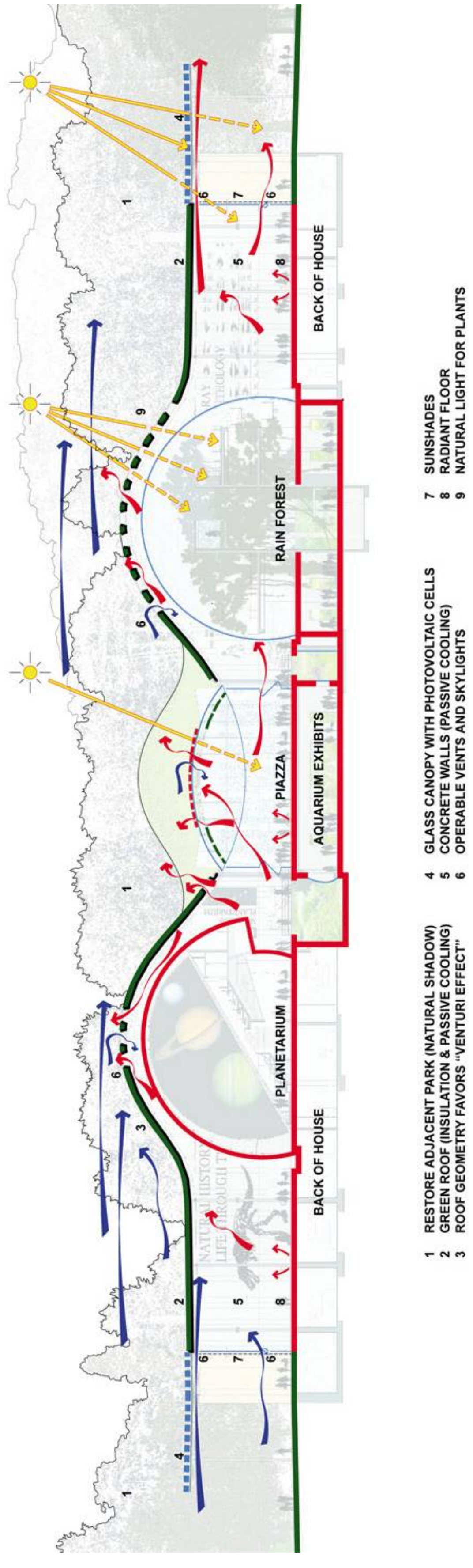

Figure 4.6. Section, California Academy of Sciences
(by courtesy of Renzo Piano Building Workshop)

The glass canopy covered with photovoltaics surrounds the green roof and constitutes an alternative sustainable energy resource to be used to function the building. The concrete walls also have a positive effect on the passive heating and cooling of the building as they have a high insulating coefficient. The vents and skylights on the green roof enable the operators to select the best time to open them and ventilate the interior spaces with cool air in need. These vents and skylight also provides natural light for the plants in rainforest dome (Figure 4.7). The sunshades below the glass canopy also helps to control the daylight penetrating into interior spaces to prevent glares and rejects additional heat losses. The floor of California Academy of Sciences designed in a way that it has the capacity of a radiant floor to control and maintain the heat of the building.

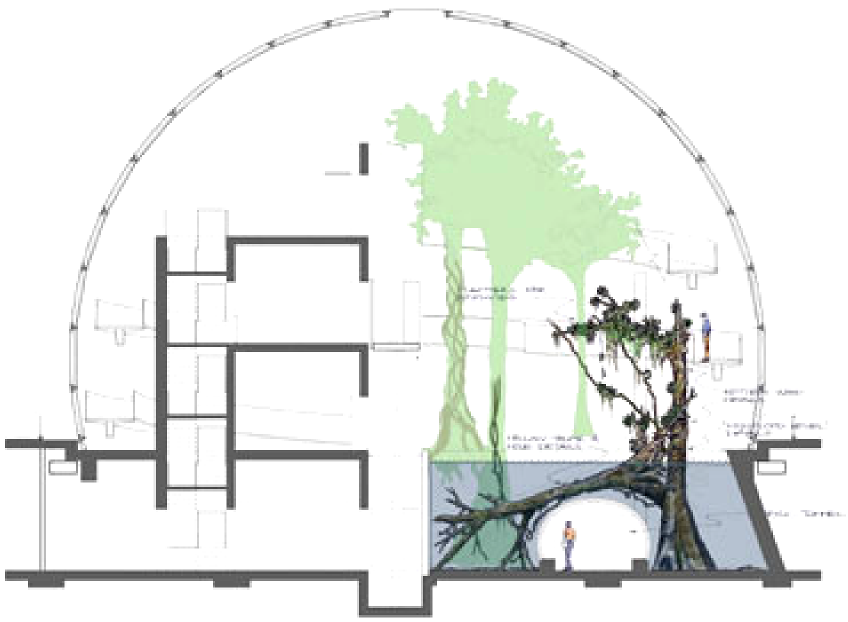

Figure 4.7. Rainforest Dome, California Academy of Sciences (http://www.arcspace.com/architects/piano/cas/academy_of_science_17.jpg, July 2010)

Figure 4.8. Interior Space, California Academy of Sciences (http://www.theepochtimes.com/n2/images/stories/large/2008/09/22/19_rainforest _exterior_web.jpg, July 2010)

A view from interior space (Figure 4.8) also gives us an idea of the environmental quality of the interior spaces. As mentioned on the previous paragraphs, that the building uses passive systems, the inner space is also a very good example of using daylighting. Since the green roof has some openings for ventilating the interior, these openings on the roof also function as a daylighting element.

The design team of California Academy of Sciences gave great importance on indoor environmental quality that they almost got all the points on the related category of LEED building assessment system.

Figure 4.9. View from Green Roof, California Academy of Sciences (http://www.greenroofs.org/baltimore_files/awardsimg2008/hiresimgs/CAS_Domes.jpg, July 2010)

Since the green roof of California Academy of Sciences building is crucial both for daylighting and passive ventilation of the interior, the location of the openings is also important to gain maximum efficiency on ventilation and daylighting. A view from the green roof (Figure 4.9) will make us understand the system of the roof better. The greening on the roof also has a function of insulation as soil has a high insulation value which also helps to improve the indoor environmental quality of the building. When looked carefully at Figure 4.9, some solar panels can also be seen that help to gain some of the energy, needed for the functions of the building, from sun.

4.2. LEED Scoring

After having general information of California Academy of Sciences building, this section of the thesis will focus on the LEED performance of the building. Analyzing the scoring performance of California Academy of Sciences will give us an idea on which categories the building gained points.

Table 4.1. LEED Scoring - Sustainable Sites (USGBC, 2010)

Credit Explanation	**Points**
Erosion & Sedimentation Control	-
Site Selection	1
Development Density	1
Brownfield Redevelopment	1
Alternative Transportation, Public Transportation Access	1
Alternative Transportation, Bicycle Storage & Changing Rooms	1
Alternative Transportation, Alternative Fuel Vehicles	1
Alternative Transportation, Parking Capacity & Carpooling	1
Reduced Site Disturbance, Protect or Restore Open Space	1
Reduced Site Disturbance, Development Footprint	1
Storm water Management, Rate & Quantity	1
Storm water Management, Treatment	1
Landscape & Exterior Design to Reduce Heat Islands, Non-Roof	1
Landscape & Exterior Design to Reduce Heat Islands, Roof	1
Light Pollution Reduction	1

When looked deeply on the sustainable site scoring performance of the buildings, it can be clearly analyzed that the building got all possible 14 points from this category of LEED building assessment system. Erosion and sedimentation control is a prerequisite in this category. The design team of California Academy of sciences gave great importance on the site of the building and this consideration ended up in a perfect scoring in this scoring category.

Figure 4.10. Exterior View, California Academy of Sciences (http://static.guim.co.uk/Guardian/artanddesign/gallery/2008/nov/03/architecture-usa/GD9401577@California-Academy-of-6354.jpg, July 2010)

The building is designed in a way to adapt to its surrounding both in brown field development, site selection and landscape and exterior design (Figure 4.10). The exterior view taken from an exhibition day of California Academy of Sciences shows the key factors of the building in a way it is in a harmony with its surrounding with the inputs the design team gave in terms of sustainable site criterions and the LEED assessment in Sustainable Site category proves it by getting a perfect score from this assessment category.

Table 4.2. LEED Scoring – Water Efficiency (USGBC, 2010)

Credit Explanation	**Points**
Water Efficient Landscaping, Reduce by 50%	1
Water Efficient Landscaping, No Potable Use or No Irrigation	1
Innovative Wastewater Technologies	1
Water Use Reduction, 20% Reduction	1
Water Use Reduction, 30% Reduction	1

As in the sustainable site scoring category, the building got all possible 5 points from the category of water-efficiency category of LEED. The effects of designing a sustainable site can be seen on the water-efficient landscaping point. Since the building got every point from sustainable site category and water efficiency of the site is also crucial, the building also got the water efficient landscaping point in this category. The building got all points of water use reduction and the cleverly designed green roof is the reason for this.

Figure 4.11. Green Roof, California Academy of Sciences
(http://farm2.static.flickr.com/1069/1435599318_ebec025fae.jpg, July 2010)

The slope of the green roof and ups and downs of it (Figure 4.11) makes it very easy to direct the rainwater or storm water and in the end collect in a big one space which then can be used to reduce the water use loads of the building.

Figure 4.12. Glass Roof, California Academy of Sciences

(http://3.bp.blogspot.com/_Odu7eqW6gAY/SzoxC4Nv94I/AAAAAAAARDU/UTo1ov3_8ts/s400/California+Academy+of+Sciences+by+Renzo+Piano+Building+Workshop+09.jpg, July 2010)

The glass part of the green roof (Figure 4.12) is lower in terms of level than the other sections of the green roof and the rainwater collection system in located here to collect the rainwater and this collected rainwater is used to irrigate plants on the green roof – a water efficient landscaping. This is the reason where the building got water efficient and water use reduction points from LEED's related assessment category.

The wastewater is also a consideration point for the design team so they also gave great importance on this topic and in the end got their innovative wastewater technologies point from this category.

Table 4.3. LEED Scoring – Energy & Atmosphere (USGBC, 2010)

Credit Explanation	**Points**
Fundamental Building Systems Commissioning	-
Minimum Energy Performance	-
CFC Reduction in HVAC&R Equipment	-
Optimize Energy Performance, 15% New / 5% Existing	1
Optimize Energy Performance, 20% New / 10% Existing	1
Optimize Energy Performance, 25% New / 15% Existing	1
Optimize Energy Performance, 30% New / 20% Existing	1
Optimize Energy Performance, 35% New / 25% Existing	0
Optimize Energy Performance, 40% New / 30% Existing	0
Optimize Energy Performance, 45% New / 35% Existing	0
Optimize Energy Performance, 50% New / 40% Existing	0
Optimize Energy Performance, 55% New / 45% Existing	0
Optimize Energy Performance, 60% New / 50% Existing	0
Renewable Energy, 5%	1
Renewable Energy, 10%	0
Renewable Energy, 15%	0
Additional Commissioning	1
Ozone Depletion	1
Measurement & Verification	1
Green Power	1

The building got 9 points for possible 17 points from the category of Energy & Atmosphere. The first three topics; Fundamental Building Systems

Commissioning, Minimum Energy Performance, CFC Reduction in HVAC&R Equipment, are the prerequisites of this category so the design team covered these topics. Optimizing energy performance is the most important issue in the scoring category and the building got four points from this optimization. Since the design team gave importance of the energy performance of the building, getting four points from energy optimization is an act to be proud of for the design team. Renewable energy is also crucial for scoring.

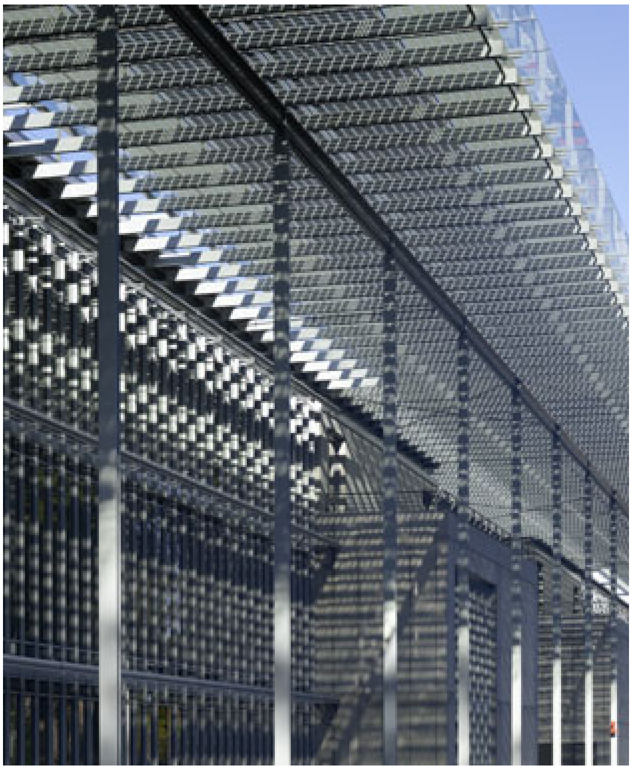

Figure 4.13. Glass Canopy, California Academy of Sciences (http://www.arcspace.com/architects/piano/cas/academy_of_science_10.jpg, July 2010)

Figure 4.14. Photovoltaics on Glass Canopy, California Academy of Sciences (http://3.bp.blogspot.com/_0zKcKumK5as/SHVWzJlLNgI/AAAAAAAAAFA/KDxPpO52dgY/s400/25722e80-bf22-49ac-94a8-f938d5ef199f.Large.jpg, July 2010)

The solar panels on the glass canopy (Figure 4.13 and 4.14) surrounding green roof made it easy to get a point from renewable energy credit. The building got other four points; additional commissioning, ozone depletion, measurement & verification, green power, and in the end did very well on energy & atmosphere scoring category of LEED. The insulating properties of the green roof, concrete walls and radiant floor also enabled the building to score points for optimizing energy performance.

Table 4.4. LEED Scoring – Materials & Resources (USGBC, 2010)

Credit Explanation	**Points**
Storage & Collection of Recyclables	-
Building Reuse, Maintain 75% of Existing Shell	0
Building Reuse, Maintain 100% of Shell	0
Building Reuse, Maintain 100% Shell & 50% Non-Shell	0
Construction Waste Management, Divert 50%	1
Construction Waste Management, Divert 75%	1
Resource Reuse, Specify 5%	1
Resource Reuse, Specify 10%	0
Recycled Content, Specify 5%	1
Recycled Content, Specify 10%	1
Local/Regional Materials, 20% Manufactured Locally	1
Local/Regional Materials, of 20% Above, 50% Harvested Locally	0
Rapidly Renewable Materials	0
Certified Wood	1

The building got 7 points from possible 13 points from the materials & resources scoring category. The first issue; storage and collection of recyclables, is a prerequisite and since the design team gave importance of recycle, they fulfilled this topic. Since the building got no shell, the design team did not score in the following three building reuse topic. Waste management is also an important issue for the design team and they even controlled the waste management in the construction phase of the building and got two points from construction waste management topics. As reuse and recycle is important for the design team, resource reuse is also crucial and they got one point from this issue and two from recycled content issue. For the sake of reducing transportation loads of the materials used to construct the building, the design team used local materials and got a point from this issue (Figure 4.15).

Figure 4.15. View from Aquarium, California Academy of Sciences (http://blog.svconline.com/briefingroom/wp-content/uploads/2008/10/22_water_planet.jpg, July 2010)

Figure 4.16. Certified Wood Use, California Academy of Sciences (http://www.archnewsnow.com/features/images/Feature0245_01x.jpg, July 2010)

The last point from the scoring category is gained for using certified wood for construction (Figure 4.16) and in the end the design team caused an adequate scoring performance from this scoring category of LEED.

Table 4.5. LEED Scoring – Indoor Environmental Quality (USGBC, 2010)

Credit Explanation	**Points**
Minimum IAQ Performance	-
Environmental Tobacco Smoke (ETS) Control	-
Carbon Dioxide Monitoring	1
Ventilation Effectiveness	1
Construction IAQ Management Plan, During Construction	1
Construction IAQ Management Plan, Before Occupancy	1
Low-Emitting Materials, Adhesives & Sealants	1
Low-Emitting Materials, Paints	1
Low-Emitting Materials, Carpet	1
Low-Emitting Materials, Composite Wood & Agrifiber Products	1
Indoor Chemical & Pollutant Source Control	1
Controllability of Systems, Perimeter	1
Controllability of Systems, Non-Perimeter	0
Thermal Comfort, Comply with ASHRAE 55-1992	1
Thermal Comfort, Permanent Monitoring System	1
Daylight & Views, Daylight 75% of Spaces	1
Daylight & Views, Views for 90% of Spaces	1

The building got 14 points from possible 15 points from the Indoor Environmental Quality scoring category. The first two topics; minimum IAQ performance and environmental tobacco smoke control, are prerequisites of this category and the design team fulfilled this topics since these two topics are also crucial for global warming. The building got its own carbon dioxide monitoring system to control the indoor air quality and got the point related with this issue. The design team gave importance on the effectiveness of the ventilation systems since it is also related with the energy use of the building. Selected effective ventilation systems gave one point for the building.

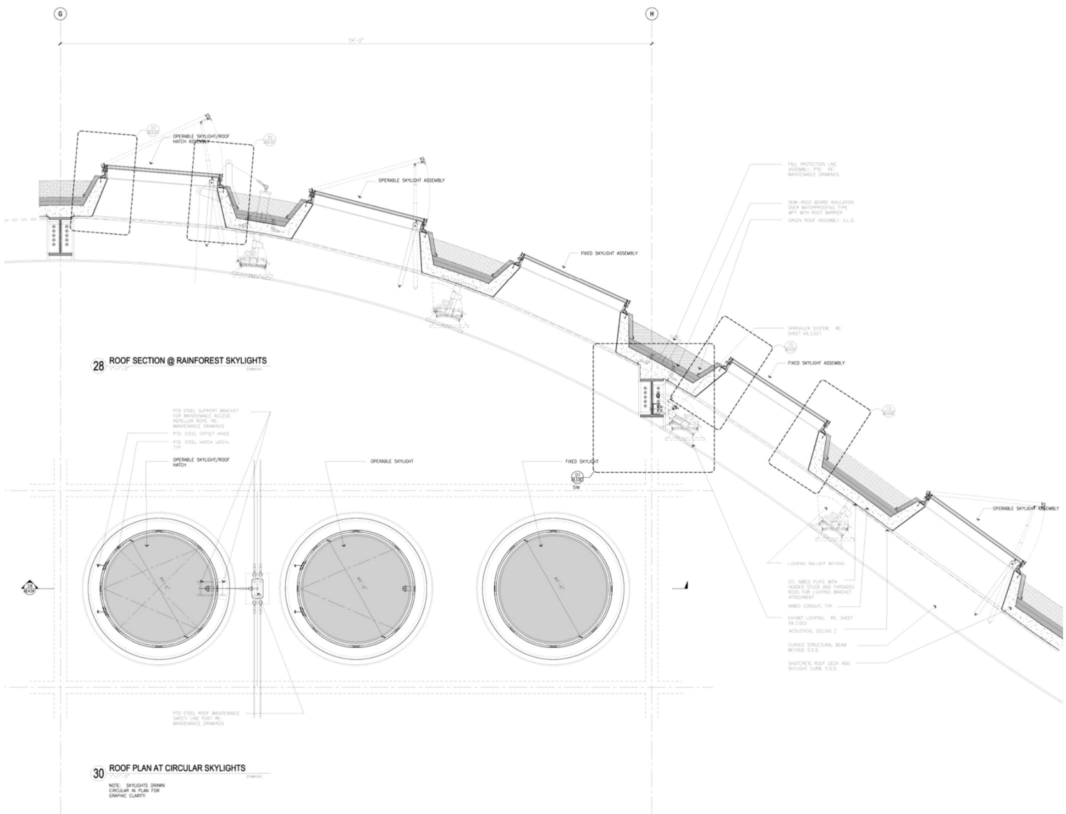

Figure 4.17. Green Roof Detail Section, California Academy of Sciences
(by courtesy of Renzo Piano Building Workshop)

Ventilating interior spaces also start from the green roof as it has many slits and openings on it that can be controlled remotely to make sure the indoor environmental quality of the occupants is in an adequate level. The detail drawing of these openings (Figure 4.17) shows these control units.

The design team also gave importance on the operating of indoors and got all points from construction IAQ management plan topic. Since the indoor environmental quality is also related with the selected materials to be used to construct a building; the use of low-emitting materials was also crucial for the design team and got all points from low-emitting materials topics. The building got its indoor chemical and pollutant source control to improve the indoor quality of it and LEED awarded the building by giving its related point.

Controllability of systems is also crucial in the case of having a good indoor environmental quality for the occupants of the building and the building got its own perimeter based control system. This system enables to control the slits and opening on the green roof, opens or closes them in order to ventilate or heat the interior spaces to maximize the indoor environmental quality of the building. Since no non-perimeter based control system is used in the building, the building got the point from perimeter based control system topic. In the case of having a good indoor environmental quality for the occupants of the building, the thermal comfort of the building is also crucial in order not to have overheated interior spaces especially on communal spaces like café (Figure 4.18). The design team gave great importance on this as they also know the importance of thermal comfort for the indoor environmental quality and they keep in touch with the latest thermal comfort standards (ASHRAE 55-1992) and had their own monitoring system.

Figure 4.18. Cafe, California Academy of Sciences (http://divineinteraction.files.wordpress.com/2008/12/img_0761_firstpost.jpg?w=470&h=352, July 2010)

These efforts made it very easy for the design team to gain two points from thermal comfort topics of this scoring category. The design team also gave importance on the daylighting performance of the building and designed the openings on the green roof not only to ventilate the building, but also provide adequate daylight to the interior spaces (Figure 4.19). The galleries and semi-leveled stories made it very easy for the occupants to grasp every interior space at once (Figure 4.20). This given importance on daylighting ended up with two points from daylight and views topics. In the end, the building got 14 points out of 15 possible points from the indoor environmental quality scoring category of LEED and showed almost a perfect scoring performance on this category.

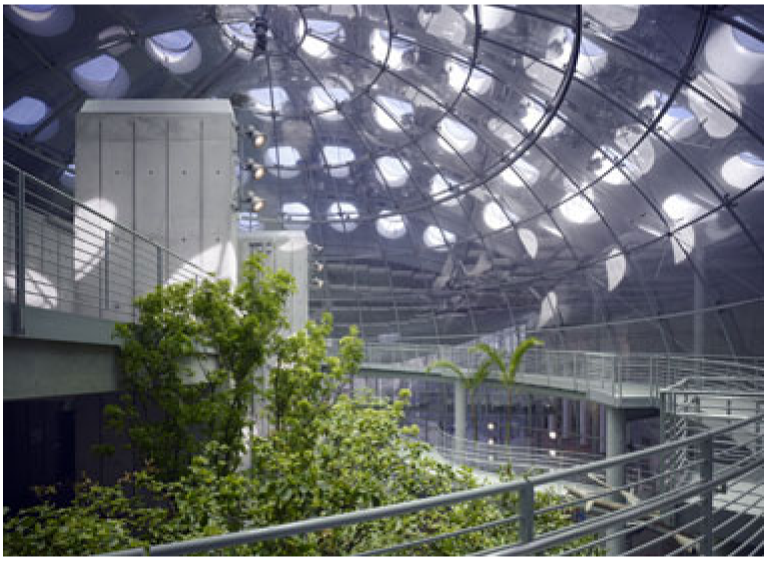

Figure 4.19. Daylighting in Rainforest, California Academy of Sciences (http://2.bp.blogspot.com/_3I_MsAGX584/SeZFcm7Lb6I/AAAAAAAAEK8/wck2VUYYBbI/s320/lighting1.jpg, July 2010)

Figure 4.20. Daylighting in Interior Space, California Academy of Sciences (http://gosanfranciscocard.com/blog/files/2009/05/ca-academy-planetarium_and_coral_reef.jpg, July 2010)

The glass modules on the facade of the building that have remote control shutter also helps the operators to control the daylight penetrating into the building and avoids additional glares that would harm the indoor environmental quality of the interior space. These glass modules also help daylight to penetrate to the deeper sections – to the domes – of the building and reduces the energy needed to light those areas in daytime (Figure 4.21).

Figure 4.21. Daylighting, California Academy of Sciences (http://www.trendir.com/ultra-modern/california-academy-of-sciences-3.jpg, July 2010)

The glazing parts of the green roof – the skylights - also have an effect on the daylighting factor of the building where the daylight penetrates from the roof is highly needs for deeper spaces of California Academy of Sciences (Figure 4.22 and 4.23).

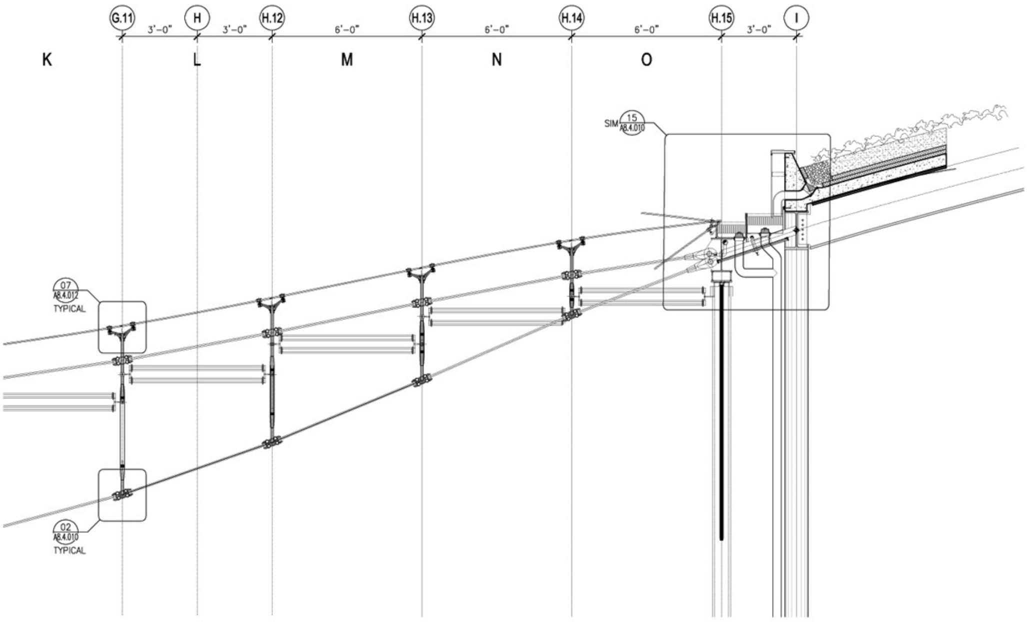

Figure 4.22. Skylight Truss Detail Section, California Academy of Sciences
(by courtesy of Renzo Piano Building Workshop)

Figure 4.23. View of the Skylight, California Academy of Sciences
(http://philipsgardenblog.com/__oneclick_uploads/2008/10/academy03.jpg, July 2010)

Table 4.6. LEED Scoring – Innovation & Design Process (USGBC, 2010)

Credit Explanation	**Points**
Innovation in Design: Transportation Incentives	1
Innovation in Design: Green Building Education	1
Innovation in Design: Pest Management	1
Innovation in Design: Flexible Exhibition System	1
LEED Accredited Professional	1

The last scoring category of LEED is the Innovation & Design Process category and the building got all available 5 points from this category. The design team gave great importance on the transportation issue and designed their site and building so that transportation is no more a problem for the occupants of this building and got their point from this topic. Green Building Education is crucial both for the sake of sustainable development and having a sustainable society; and the design team had an emphasis on this topic as they again got their related point. The green roof has plantings on it to have a great insulating layer (soil is a great insulating efficiency) to improve the thermal performance of the building.

This input also created a new topic for the design team; pest management. They gave importance on it and gained their point from this topic also. Since the building is also an exhibition center, the flexibility of the exhibition systems was crucial for the design team and they also got a point from this. The last point was gained from having a LEED accredited professional in the design process. This enabled them to control the documentation process of LEED assessment and design their building in a way to have a great LEED scoring performance in the end which will give the building an advance on marketing, both California Academy of Sciences and Green Buildings in general.

In the end, California Academy of Sciences got 54 points from available 69 points and gained a Platinum certification from LEED building assessment system. The points gained from each criterion will also clarify that which topics and issues the design team gave importance in the process of designing the building.

Looking into the LEED scoring performance of the building, there are four important categories for the design team: sustainable site, water efficiency, indoor environmental quality and innovation & design process. From these categories of LEED assessment system, the building almost gets all the available points which indicate the importance given by the design team.

Since the building uses also passive systems for heating, cooling and daylighting, some major points from the category energy & atmosphere are gained in the end. The building also gives importance on the materials used in the construction phase of it and this importance can be read from materials & resources category of the assessment.

Combining these aspects and assessing California Academy of Sciences with LEED building assessment system gives us a better understanding of the practical use of assessment systems on buildings.

As the selected building is a major architectural example and the design team gave great importance on sustainable development, the building got almost every point in each category of LEED assessment system which will in the end add up and give the building a Platinum LEED scoring – the highest level of scoring in LEED building assessment system.

4.3. Scoring California Academy of Sciences with Other Building Assessment Systems

After looking deeply on the scoring performance of California Academy of Sciences with LEED building assessment system; the next point will be to assess the building with other building assessment systems to clarify the advantages of LEED on these other building assessment systems. The following sub-chapters will clarify which categories or aspects would the building gain and lose points if it would be rated with BREEAM, CASBEE and GreenStar. The following sections will focus on additional assessments of California Academy of Sciences with BREEAM, CASBEE and GreenStar building assessment systems.

4.3.1. Scoring with BREEAM (UK)

After analyzing the LEED scoring of California Academy of Sciences, it will be helpful to compare the results with BREEAM scoring of the building in terms of getting an idea on the advantages of LEED on BREEAM. Since the aim of the thesis is to clarify the major advantages of LEED building assessment system on other assessment systems, BREEAM is the first assessment system for the building to be rated in an imaginarily way.

The additional scoring of the building with BREEAM building assessment system will clarify the differences between LEED and BREEAM building assessment systems. By focusing on the differences between these two building assessment systems, this section will rate California Academy of Sciences using BREEAM.

The credits of BREEAM are not also the same as the LEED system. There are several credits that reflect the LEED credit in every way, but there are also different credits requires some calculations in BREEAM building assessment system.

Since California Academy of Sciences is rated with LEED building assessment system, rating it with BREEAM will focus on imaginary ratings of each category. The first category in BREEAM is the Management category. LEED has no direct category named "management" so there is no concrete information in order to fully assess the management performance of the building with respect to BREEAM. But since this category of BREEAM includes site investigation and commissioning -and it is known from the LEED scoring that the building considered those issues - we could say that it can get an overall score from this category.

The next category of BREEAM is the Health and Wellbeing category which is very similar to the credits of Indoor Environmental Quality category of LEED assessment system. The building almost got every point in that category of LEED and since this category of BREEAM is similar to this, it can also get almost every point from this scoring category of BREEAM.

Energy scoring category of BREEAM is also similar to the Energy and Atmosphere scoring category of LEED. It is known from the LEED scoring chart that the building got an overall scoring from LEED assessment and could be said that would get also an overall scoring from this scoring category of BREEAM.

The next category of BREEAM is the transport category. We do not have a concrete data on this issue as LEED does not have a similar scoring category but since the design team of the building also considered this issue, which could be said that the building could get an overall score for transport category of BREEAM.

Water category of BREEAM is crucial as this category is closely related with the sustainable development of the society and our surroundings. This scoring category is very similar to the Water Efficiency scoring category in LEED. The building got every possible point from this category, since it is very similar to the one in BREEAM, we could say that the building will again get all the possible points from this scoring category of BREEAM.

Materials scoring category of BREEAM is also very similar to the Materials & Resources scoring category in LEED. LEED scoring performance of the building shows that the building got an overall score from this category. Keeping in mind the LEED scoring performance based on this category, it can be asserted that the building would also get an overall score from Materials scoring category of BREEAM.

Waste category of BREEAM is a crucial sustainable category especially during the construction phase of the building. There is no concrete data since LEED has no direct assessment category named “Waste” in BREEAM. But we know from the LEED scoring tables that the building considered and got points from construction waste management. Since this credit is important in Waste category of BREEAM, we could say that the building is capable of getting an overall score from this category of BREEAM.

Land Use & Ecology scoring category of BREEAM has no similar category in LEED building assessment system and about this category we do not have any concrete data. But since the design team considered land use and got several points from these issues in LEED scoring, it can be asserted that the building will get an average score from this category of BREEAM.

Pollution scoring category of BREEAM has also no similar category in LEED system. But when looked deeply into the Energy and Atmosphere category in LEED, it can be seen that the building achieved the related points from this category. Keeping in mind these related points; we could say that the building is capable of getting an average score from Pollution scoring category of BREEAM.

The last scoring category of BREEAM is the Innovation category. Since LEED also has a similar category named Innovation and Design Process and got every possible points from this category, it can be said that, if an imaginary assessment is done with using BREEAM, the building will again get every possible points from this category.

Keeping in mind the imaginary assessment of California Academy of Sciences building with BREEAM, it can be said that the building is capable of getting an "Excellent" certification from BREEAM building assessment system. Since LEED and BREEAM are very similar and include common categories, the results are not confusing; the building got Platinum certification from LEED and would likely achieve "Excellent" certification from BREEAM. But getting an "Excellent" certification from BREEAM required to collect more data as the number of credits and assessment categories of BREEAM is more than LEED. This additional data resulted in additional effort to look at in the design phase in this imaginary assessment and would cost higher and need extra time in the real life if the building is to be assessed with BREEAM assessment system. There are also some categories of BREEAM that has no similar title in LEED, but when examined closely the scoring categories of LEED, similar credits can be obtained and adapted to BREEAM assessment system. These similar credits enabled to assess this kind of scoring categories of BREEAM through this section of the thesis.

Rating California Academy of Sciences with BREEAM also clarifies that LEED also covers a wide view in terms of sustainable construction as BREEAM assessment system. But BREEAM needs more technical and mechanical data for its specific credits than LEED which makes BREEAM a complex system in some specific assessment categories. This is one of the reasons why LEED is the widespread building assessment system used.

The number of assessment categories of BREEAM is more than the assessment categories of LEED, which makes the design teams to collect more data in term of the construction of their building and the scoring of California Academy of Sciences building with BREEAM enabled to experience these issues. To summarize, if BREEAM were selected to assess the building, it would both cost an extra expense for the design team and extra time; in this sense LEED provided a better way of assessment.

4.3.2. Scoring with CASBEE (Japan)

Scoring California Academy of Sciences with CASBEE will give a better understanding of the differences between LEED and CASBEE building assessment systems. The scoring performance of the building with LEED is used to transfer the data to an imaginary CASBEE assessment of the building to address the advantages and disadvantages of CASBEE on LEED.

The first assessment category of CASBEE is the Noise and Acoustics category. LEED has no such category within its structure, but through the separate points in different categories it can be asserted that the building would get an average scoring from this category.

Thermal Comfort assessment category is much more like LEED's points in Indoor Environmental Quality category. The building got all related points in thermal comfort issue in LEED assessment. In this sense, it can be asserted that it would get all available points from CASBEE, too.

Lighting and Illumination assessment category is the next category of CASBEE. The building got related points from daylight and view and controllability of systems in Indoor Environmental Quality assessment category of LEED. This category of CASBEE requires the same issues to be assessed, in this sense; the building would get all available 3 points from this assessment category.

The next assessment category of CASBEE is the Air Quality category. The related points are gained from ventilation effectiveness; construction management plans points from LEED assessment. Since this category of CASBEE requires these topics, it can be asserted that the building is capable of getting all available 3 points from this assessment category.

The next scoring category of CASBEE is Service Ability. LEED has no similar category but some consideration can be found on Sustainable Site category of LEED. In this sense, it can be asserted that the building would get an average score from this assessment category.

Durability & Reliability and Flexibility & Adaptability assessment categories do also not exist in LEED. Since there is no concrete data and this assessment category of CASBEE requires additional calculations, it can be asserted that the building would get an average score from these scoring categories keeping in mind the flexible exhibition system point of the building in Innovation and Design Process assessment category of LEED.

Outdoor Environment of Site and Energy assessment categories of CASBEE are very similar to the Sustainable Sites and Indoor Environmental Quality categories in LEED. Since the building got every available point from LEED assessment, it could be asserted that the building is capable of getting all available points from CASBEE's related assessment categories.

Resources and Materials scoring category of CASBEE is titled almost the same in LEED as Materials and Resources. The consideration of CASBEE in this category is different than LEED as CASBEE includes water resources, too. Since there is no consideration on this issue in LEED, it can be asserted that the building would get an overall score from this scoring category.

Off-site Environment assessment category is the last category of CASBEE as related points could be found in the Sustainable Site and Energy & Atmosphere assessment categories of LEED assessment system. In this sense, it can be asserted that the building would get total scoring from this scoring category of CASBEE.

Keeping in mind the scoring assumptions made in the previous paragraphs, it can be asserted that, California Academy of Sciences building would get 5-star certification if an imaginarily assessment is done by using CASBEE building assessment system. Some categories of CASBEE do not directly exist in LEED but the points in that related non-existing categories can be found separately of different assessment categories of LEED.

To summarize, CASBEE is a more complex building assessment system than LEED that uses technical and mathematical calculations within its structure where the simple structure of LEED is a major advantage in this issue. Throughout this imaginary assessment of California Academy of Sciences with CASBEE, these calculations played an important role as more data is needed for design team to be assessed with CASBEE. The scoring structure of CASBEE is also different from LEED as each scoring category of CASBEE totals to 3 points where the assessment category points of LEED differs slightly.

After experiencing these major technical calculation problems of CASBEE with this assessment of California Academy of Sciences, it could be said that LEED differs CASBEE in terms of its simple assessment categories, single-point scoring system and most important the ease of use.

4.3.3. Scoring with GreenStar (Australia)

Scoring California Academy of Sciences with GreenStar building assessment system will also give us a better understanding on the differences between LEED and GreenStar. Looking deeply into the scoring categories of GreenStar and making an imaginary assessment will be followed in this section.

The first scoring category of GreenStar is the Management category and as in the BREEAM assessment, there is no similar scoring category in LEED that we can count on for concrete data. But since commissioning, environment and waste management are the important issues in this category of GreenStar and the design team got points in those issues in LEED, we could say that the building is capable of getting an overall score from this category of GreenStar.

Indoor Environmental Quality scoring category is the following category of GreenStar. Since LEED also has a same entitled category and the building got almost every point from that category, keeping in mind the specific points of GreenStar in this scoring category; it can be asserted that the building would again get almost every point from this category of GreenStar.

Energy scoring category of GreenStar is also very similar to the Energy and Atmosphere scoring category in LEED. The building got an overall scoring from that category of LEED. Keeping in mind this data with regard to the points in GreenStar system, it can be asserted that the building is capable of getting an overall score from this category of GreenStar.

The next scoring category of GreenStar is the Transport category. As in the imaginary BREEAM scoring section, there is no similar category in LEED system that we can compare. But as we know that the design team considered mass transportation and car parking, we could say that the building can easily get an overall score from this category of GreenStar also.

Water scoring category of GreenStar is very similar to the Water Efficiency scoring category of LEED in term of credits and issues considered. Since the building got every possible related point from LEED system, it can be mentioned that the building is capable of getting again all possible points from Water scoring category of GreenStar.

The next scoring category of GreenStar is the Materials category. This category also is very similar to the Materials and Resources scoring category of LEED. When looked into the LEED scoring performance of the building, it can be observed that the building got an overall score from this category. Keeping in mind this data, we could say that the building could easily get an overall score from this category of GreenStar.

Land Use & Ecology scoring category of GreenStar concentrates on the impacts and ecological effects of the building to its surrounding. LEED has no similar category with this category but when looked into the credits of this category of GreenStar, it can be seen that the building got some related points in different categories in LEED assessment system. Through this, the building is capable of scoring an overall score again from this category.

Emissions scoring category of GreenStar has also no similar category in LEED system. But the building is capable of getting an average score from this category of GreenStar as it got a few related points from LEED scoring.

The last scoring category of GreenStar is the Innovation category. LEED has also the same titled category within itself. Keeping in mind the building got every possible point from LEED scoring, it can be asserted that it is capable of getting every point from this category of GreenStar building assessment system also.

The separate analysis of the scoring categories of GreenStar clarifies that, if an imaginary assessment would be done on California Academy of Science using GreenStar – keeping in mind the LEED scoring performance of the building and the technical data given to get a LEED certification - the certification grade would be Six Star certification; the highest certification degree in GreenStar building Assessment System.

Since GreenStar is highly inspired by LEED and BREEAM building assessment systems, there are several scoring categories that they also exist in LEED and BREEAM. The points from categories that do not exist in LEED were calculated as some related points were gained in different categories.

GreenStar building assessment system has more assessment categories like BREEAM than LEED building assessment system. The weighting of the assessment categories and the details of each credit is also different from LEED building assessment system. If GreenStar is selected to assess the building, as in the BREEAM example, this would require more data, money and time of the design team. Experiencing these issues as in the BREEAM scoring of California Academy of Sciences; with its simplicity of use, user friendly structure and simple checklist scoring format, LEED requires a better assessment than GreenStar for the design team and owner of the building.

With the help of these additional assessments of California Academy of Sciences building by using BREEAM, CASBEE and GreenStar; the major advantages of LEED, like its simple structure, ease of use, are clarified. In this sense it could be said that LEED building assessment system is still the most applicable assessment system among these assessment systems.

CHAPTER 5

CONCLUSIONS

Nowadays, Sustainable Development is gaining great importance as each day more sustainable buildings are surrounding us. Since the number of sustainable buildings is increasing, the control mechanism is needed in order to classify them. In this sense, it is the building assessment systems that undertake this role.

There are many building assessment system like LEED, BREAM, CASBEE, Green Star used globally to guide the owners of the buildings and design teams in the process of constructing a sustainable surrounding for us. But through these building assessment systems LEED is the building assessment system that is wide-spread used all around the world both with its original structure and with some changes and integrations (as in the example of GreenStar building assessment system used in Australia) on the structure of it.

The aim of the thesis was to deeply analyze why LEED building assessment system is simple and user-friendly – different from other building assessment systems and prove the advantages of LEED on other selected building assessment systems in terms of its simplicity. In this sense other major building assessment systems from different continents is analyzed through the thesis – BREEAM, CASBEE and GreenStar – to show the diversity of building assessment systems around the World.

The hypothesis is that LEED building assessment systems is being used wide-spread because of its simplicity for users and flexibility. Through this thesis, the emphasis was on the simplicity aspect of LEED. LEED has a simple structure starting from its versions for major building types where other studied building assessment systems has more and complex versions that could confuse the users of these kinds of assessment systems. The assessment categories of LEED can also be put forward as cleverly organized where major issues in terms of sustainable design are emphasized in 5 categories; sustainable site, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality.

The single point scoring system has also an effect on its simplicity while a building assessment system like CASBEE uses whole different and complicated scoring systems that use technical calculations and graphics. Besides its simplicity, LEED building assessment systems is also a flexible system and being upgraded gradually with some additional properties by USGBC.

To get to these results, first the selected 4 building assessment systems – LEED, BREEAM, CASBEE and GreenStar – were analyzed in Chapter 2 with regard to their historical backgrounds, origins, structures, assessment categories and certification processes. After examining and having a general understanding of the building assessment systems, comparisons between these systems and LEED was made in Chapter 3. These comparisons were divided into sub-chapters as comparisons in their general properties, assessment categories and scoring systems.

The findings clarified that LEED has many advantages on other building assessment systems in terms of its simple, clear assessment categories and single point scoring system. In order to extend these findings a case study is selected - California Academy of Sciences - and being analyzed in Chapter 4. After analyzing the selected case study, by using the accessed LEED scoring sheet of the building from USGBC's webpage, the LEED assessment of the building is explained and proved by using figures.

Analyzing California Academy of Sciences building focusing on LEED building assessment system indicated the practical use of LEED in design and construction phase. The additional BREEAM, CASBEE and GreenStar scoring of the same building showed the major advantages of LEED on other used building assessment systems. BREEAM and GreenStar building assessment systems has more assessment categories and credits with respect to LEED that need more data to be collected for the design team of the building that would take extra time and money for them.

By assessing California Academy of Sciences, the advantages of LEED on BREEAM and GreenStar in this issue are experienced in Chapter 4. CASBEE also has more assessment categories than LEED assessment system but what makes CASBEE different among these building assessment systems is that, this system depends on complicated mathematical and technical calculations which in the end transferred into graphical representations by the system in its separate certification page. The assessment of California Academy of Sciences building with BREEAM, CASBEE and GreenStar showed that LEED building assessment system is more advantageous with its simple structure, ease of use that made LEED a wide-spread used building assessment system.

The findings of this thesis clarifies that the sub-categories of LEED covers many important and crucial topics related to sustainable development more than other building assessment systems. As it does not have extra tools and complicated calculation, its simplicity and single point scoring system makes it a user friendly building assessment system other than other systems.

One advantage of LEED on other building assessment systems is the flexibility of it. This flexibility also gives LEED an advantage for modifications and additions as USGBS improves LEED frequently that is a proof to its flexibility.

For sure LEED is not a perfect building assessment system. The required credits in its assessment categories create a differentiation among the structure of the assessment category. These required credits are helpful as any design team is obliged to satisfy that criteria and somehow become a part of sustainable design.

But the selections of these required credits are arguable and create a dispute on the importance of each credit. This disadvantage of LEED could be easily overcome by increasing the number of required credits into the assessment categories or completely structure the whole system so that all credits are required.

Besides its minor disadvantages, it shelters a great potential with the power of its simple structure that enables any integration of sub-systems into it; and there is an ongoing discussion related with this. For future studies the integration of Life Cycle Assessment Systems and The Natural Step tools should be considered in this sense to improve the future versions of LEED. The integration of these two sub-systems would turn LEED into a must for sustainable design. For now, LEED is not a perfect building assessment system but this building assessment system provide an adequate assessment in terms of sustainable design and seem to have an important role in the future with its simple and flexible structure.

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