Comparison of Green Building Certification Systems (GBCSs): supporting the choice of the most suitable GBCS for one's project

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from

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List of Abbreviations

AHP	Analytic Hierarchy Process
BPIE	Buildings Performance Institute Europe
BRE	Building Research Establishment
BREEAM	Building Research Establishment's Environmental Assessment Method
BREEAM Int.	BREEAM International
CASBEE	Comprehensive Assessment System for Built Environment Efficiency
CI	Consistency Index
CR	Consistency Ratio
CRMs	Critical Raw Materials
DGNB	Deutsche Gesellschaft für Nachhaltiges Bauen
EA	Energy & Atmosphere
EC	European Commission
EEA	European Environmental Agency
Ene	Energy
EU	European Union
GBCS(s)	Green Building Certification System(s)
GHG(s)	Greenhouse Gas(es)
Hea	Health & Wellbeing
HQE	Haute Qualite Environnementale
HVAC	Heating, Ventilating and Air Conditioning
ID	Innovation and Design Process
IEQ	Indoor Environmental Quality
JRC	Joint Research Center
Le	Land use and ecology

LEED	Leadership in Energy and Environmental Design
LEED C&S	LEED Core & Shell
Man	Management
Mat	Materials
MCDM	Multi-criteria decision-making
MR	Materials and Resources
NC	New Construction
NISI	National Institute of Standards and Technology
NSOs	National Scheme Operators
PC	Pairwise comparison
Pol	Pollution
RES	Real Estate Sector
RI	Random Index
RMs	Raw materials
RP	Regional Priority
SS	Sustainable Sites
Tra	Transport
UK	United Kingdom
UNEP	United Nations Environment Programme
US	United States
USA	United States of America
USGBC	U.S. Green Building Council
WE	Water Efficiency
WGBC	World Green Building Council
Wst	Waste

Kurzfassung

Der Immobiliensektor kehrt langsam zu einer normalen Entwicklungsgeschwindigkeit zurück. Der dringende Bedarf an Mechanismen, die nicht nur die Umwelt schützen, sondern auch die menschliche Gesundheit und die sozialen Interessen wahren, ist seit mehr als einem Jahrzehnt vorhanden. Auf internationaler Ebene gibt es viele verschiedene ‘Green Building’-Zertifizierungssysteme, so dass die Auswahl von einem System nicht trivial ist. Um die Grundlagen für die Auswahl eines passenden Systems für ein Projekt auszuwählen, stehen die ‘Green Building’-Zertifizierungssysteme ‘LEED’ und ‘BREEAM’ im Mittelpunkt dieser Arbeit. Diese werden auf theoretischer und praktischer Ebene miteinander verglichen. Dabei wird die Methode des paarweisen Vergleichs anhand zweier Referenzprojekte angewandt. Die originale Bewertung und dessen Gewichte sind im Basisszenario 0 dargestellt, vier alternative Szenarien erlauben eine Evaluierung der beiden Zertifizierungssysteme. Die Sensitivität der beiden Zertifizierungssystemen auf eine geänderte Gewichtung der Beurteilungskriterien und dessen Auswirkung auf die Beurteilung der Referenzprojekte konnten erarbeitet werden.

Aus dem Vergleich der Szenarien für die Projekte und dem Vergleich der Ergebnisse zu einzelnen Kategorien der Zertifizierungssysteme können Erkenntnisse für die Auswahl in Abhängigkeit der Eigenschaften des zu beurteilenden Projektes gezogen werden.

Abstract

The real estate sector slowly but certainly returns to its normal pace of development as the environmental burden that it imposes. The need of mechanisms to protect not only the environment but also the human health and society's interest is on the urge for already more than a decade. On the international level there are many different Green Building Certification Systems (GBCSs), so the right choice does not always come easy. In order to lay the basics for choosing the most suitable system for a project the Green Building Certification Systems LEED and BREEAM will be the center of this study. These are compared on theoretical and practical level. The method of pairwise comparison is applied on two reference projects. The original assessment and weighting values of the two systems are presented in Baseline Scenario 0. Additionally. four alternative scenarios assist in the evaluation of the two systems. The study presents the adjustments of the certification systems' weightings and the evaluation of their sensitivity through the effect they have on the reference projects.

By comparing the scenarios for the projects and comparing the individual credit categories of the certification systems, findings about the selection of the most appropriate system for a project, depending on its characteristics, could be obtained.

Acknowledgement

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Declaration of Authorship

I confirm that this Master thesis is my own work and I have documented all sources and materials used.

This thesis was not previously presented to another examination board and has not been published.

1 Introduction

The term "*sustainability*" and its introduction by the *Brundtland Commission* in 1989 have changed the common perception about the environment and its place and relation to economic and social development on a global, national and regional level. The term is currently an inseparable part of the dynamic and rapidly changing global economical, social and environmental norms. The concept of sustainability has been a subject to a lot of discussions not only about its definitions but also about its possible implementations in regulations, economic patterns, social contracts and daily-based decision-making in different spheres. So far, there is no single agreed upon definition of sustainability, but rather recognition that it should be adjusted to the context in which it is used.

The purpose of this study is to present the implementation of sustainability concepts in the real estate sector as a key for the integration of environmental concerns provoked from the building's sector. This can be achieved in forms of regulations, initiatives or even through certification systems that promote and develop their structure around its three main pillars - economics, society and environment. The later gives real estate managers and investors the possibility to choose the extent to which they want to adopt different sustainability practices into their business, in order to meet the needs of the market and the buildings' future occupants. Therefore, it is important to understand the basic concept behind the different Green Building Certification Systems (GBCSs) and their application within the sector.

The term GBCS is nowadays used as a synonym for sustainable buildings or green buildings. The Green Building Certification Systems have been introduced into the real estate market as a tool for the integration of the sustainability concept from the planning of a building through its use and final demolition or reuse. These systems consider issues such as energy efficiency, water use reduction, occupants satisfaction (for example, indoor air quality), recycling content of materials, reduction of CO_2 emissions, reduction of the heat island effect, etc. The structure behind the systems, their goals and focuses, are presented later in a separate chapter.

The main objective of this study is to assist decision-makers in the real estate sector when choosing a green certification system for their projects, as it seeks a comprehensive answer to the question: *"How to choose the most appropriate Green Building Certification System for your project?".*

Based on research in this field and practical experience simple assumptions can be tested with the study. The following can be seen as the core hypothesis of this paper:

- Achieving higher certification in one system, in comparison to another, does not automatically suggest that the project will perform better in all its categories and will therefore achieve higher savings in spheres such as energy consumption, water consumption or resource efficiency.
- The above also applies when considering the investment returns, occupants' comfort and satisfaction.

In order to analyze these statements and find an answer to the initial question, different sectors of the real estate sector, its development and connection to the environment will be examined. The study will aim to focus mainly on Europe but also other parts of the world will be mentioned.

With the help of a multi-criteria decision-making tools and methods, i.e. pairwise comparison and scoring, a deeper understanding of the structure of Green Building Certification Systems, their environmental impact categories as well as the different importance (weightings) of these categories within the systems, will be presented.

Before going into the methodology of this study, the relations between the real estate sector and the environment is analyzed from two different perspectives – the real estate's and the environment's. The results are integrated as basis for the paper's scenarios. Later, these scenarios are applied on two chosen projects. At the end, the outcomes are compared and the initial hypothesis is tested.

1.1 The Real Estate Sector (RES) - Trends and Driving Forces

The economic crisis of 2007 has shifted the equation of the real estate sector in different directions with new challenges. Established real estate markets have crushed down, the demand of the market has shifted, the willingness of taking risk has changed, the investments have drastically decreased and new possibilities for survival has been reviewed. Indeed, the term "risk management" has adopted new meaning - the focus has been moved to the long-term risk analysis rather than the possibility of short-term returns of investments.

Recent reports and discussions show that the real estate sector is slowly but surely regaining its normal pace of development - the investments are back; the markets are stabilizing and the real estate sector players' expectations are looking into a brighter direction. According to the *PricewaterhouseCoopers and the Urban Land Institute* report on the current trends in the RES, *54 %* of the participants in their research have regained their business confidence and expectations for business profitability in 2014 (PwC and the Urban Land Institute, 2014). This may be the result of the recovery of markets, such as Ireland, Spain and even Greece, which is showing small signs of improvement. On the other hand, the big European real estate markets UK, Germany and France head for their pre-crisis development levels, due to more investments flowing from American and Asian investors (PwC and the Urban Land Institute, 2014). As previously mentioned, if pre-crisis investors were looking only for promising developments in terms of short-term financial returns, nowadays the focus is on quality assets that can bring long-term savings. Thus, different analysts predict a *4%* growth of investment for office buildings, *1%* for industrial and *4%* for unit shops in 2014 (PwC and the Urban Land Institute, 2014).The following figure presents the current most active markets within Europe.

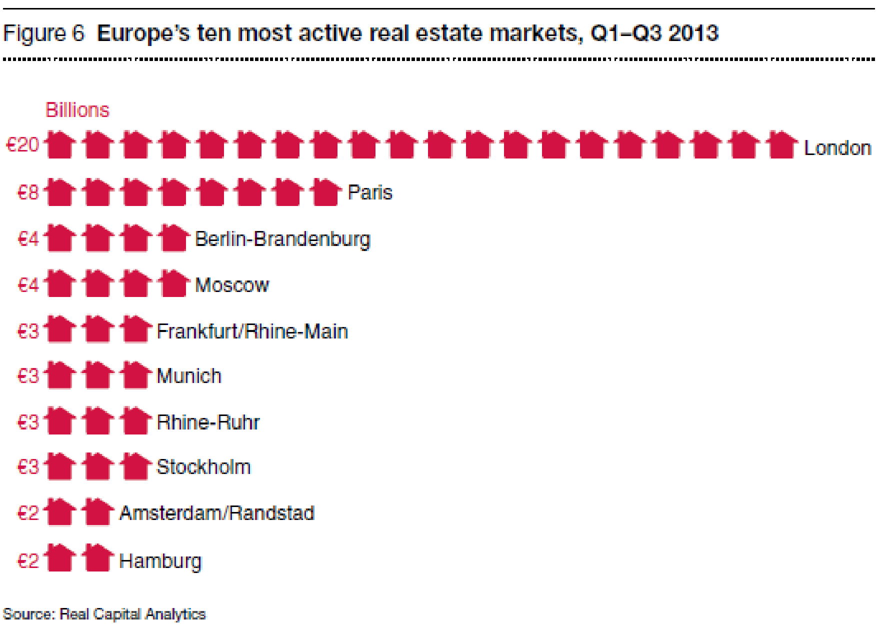


Figure 1 Europe's ten most active real estate markets

The last decade has revealed and made attractive also other possibilities for development into the sector -for example, student accommodations are considered much more profitable alternative than the commercial real estate assets (offices, retail developments, industrial, etc.). The above suggests that there is an uncertainty for the occupiers' demand. Other factors, such as demographics, are as well taken into consideration when making an investment decision. In addition, serviced apartments, retirement living and healthcare centers can also be accounted to the new alternatives for investment.

One simple explanation of this shift is the demographic changes that Europe is facing - aging of the population and the decrease of the young, working inhabitants, for instance. According to a German economist Jörg Zeuner *"by 2030, Germany's working population will have decreased by at least 8 percent"* (PwC and the Urban Land Institute, 2014). Figure 2 demonstrates how exactly the demographics can clearly move the focus of the real estate sector:

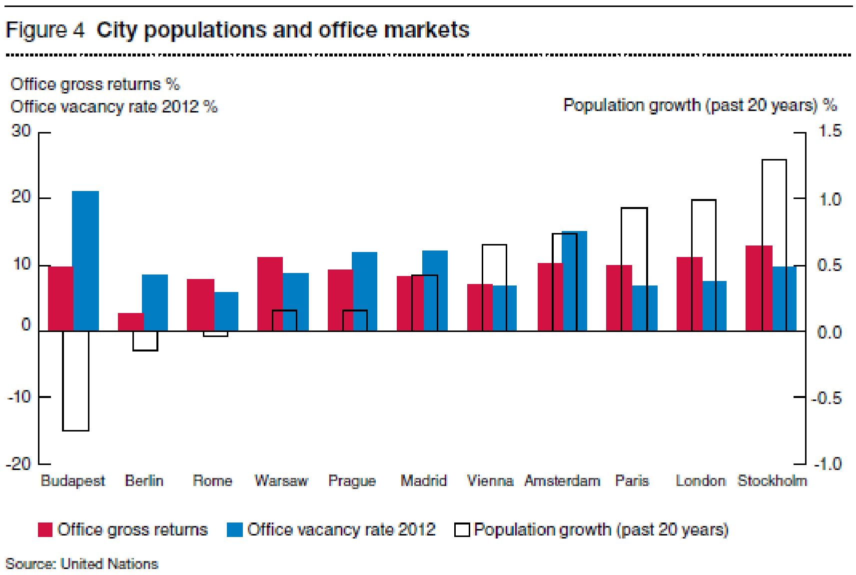


Figure 2 City populations and their influence on the office real estate sector

Additional to the financial and social factors, there are also other changes that should be considered from the decision-makers - green buildings and their place on the market. If the topic of sustainability in real estate reports has been only found in the footnotes, now it is inseparable part of day-to-day business talks.

1.2 Sustainability – Integration to the RES

There are already many mechanisms, tools and approaches available that drive the real estate sector in the direction of green buildings. These include regulations on international, national and local levels, as well as numerous initiatives which set their objectives to promote, research and analyze the opportunities for implementation of sustainable practices.

While going through numerous articles about the real estate sector and the role of sustainability, one comes across terms such as sustainability risk assessment, green building certifications, green lease, monitoring, reporting, raising environmental awareness, stakeholder engagement, competitiveness, long-term returns, buildings robustness, and others (GRESB, 2013; DLA Piper, 2014; PwC and the Urban Land Institute, 2014; McGraw Hill Construction, 2013).

Different reports suggest that lowering the construction costs of a green building can be the result of early influence in the design planning, better control and management during the construction phase, responsible sourcing, etc. (GRESB, 2013; DLA Piper, 2014; PwC and the Urban Land Institute, 2014). These are all different topics that are incorporated into a certification process with any of the Green Building Certification Systems available on the market.

The next chapter presents in details the idea, structure and goals of two GBCSs – LEED (Leadership in Energy and Environmental Design) and BREEAM (Building Research Establishment Environmental Assessment Method).

2 Green Building Certification Systems (GBCSs)

There is a need for an integrated approach that allows considering the three major pillars of sustainability, in terms of the real estate sector, in a sound manner. In other words, there is a need for a multi-attribute system that takes into consideration the complexity and the interrelations between the environment and the built environment, such as buildings.

In the past years some options have been suggested like building standards, norms and green product certification. However, most of the proposed mitigation and coping measures focus on a certain aspect only, such as energy or water savings.

With the introduction of the *Green Building Certification Systems (GBCSs*) in the beginning of the 90s, one step further has been taken. This gives the real estate developers the possibility to assess the sustainability of their assets by embracing the complexity of the different factors influencing their decisions in a more comprehensive manner without omitting important factors, such as environmental pollution, occupants' satisfaction, resource efficiency, economic savings (energy and water savings), etc. GBCSs are an opportunity to evaluate and improve the whole life cycle of a building and ensure the long-term life of a development.

Nowadays with the assistance of Green Building Certification Systems, real estate decision-makers can evaluate the sustainability level of their assets not only in the case of new construction projects, but also for already existing buildings. The first focus more on decisions taken in the planning and design stages together with activities through the construction phase. On the other hand, the second considers more closely the operation and maintenance of the building's new life and the optimization possibilities of its technical aspects and resource efficiency, for example (Verra, 2014).

Different studies discuss the advantages and disadvantages of GBCSs. In the early development of these systems, practitioners considered additional construction and design costs of *about 10%.* Since then, the building standards and norms have evolved and the latest studies show that the costs add-up to a project undergoing certification, in comparison to a normal development, lay normally between *0% and 4%* (WGBC, 2013).

Each system gives the possibility to the real estate developers to choose their level of sustainability commitment, i.e. their pursue of certification level. However, a higher level of certification may need an earlier consideration of the system's requirements in the project's development and additional construction costs. These costs can vary between *2-12%* where the lower range represents certification levels, such as "Very

Good" (BREEAM) and "Silver/Gold" (LEED) and the upper – the highest certification levels possible, for example "Outstanding" (BREEAM) and Platinum (LEED) (WGBC, 2013). Some studies suggest that the additional costs can be seen as the main disadvantage of Green Building Certifications. However, practitioners also suggest that the additional expences return within a reasonable time in the form of economic savings (for example, energy cost savings), social and economic benefits not only for the owners but for the occupants as well.

The benefits of this type of certification can be divided into three main groups: economic, social and environmental.

In economic terms, green building certifications may positively influence a project in one or more of the following aspects:

- *Improve the building's value* – not only its sale price, but also higher rental prices
- Generate *savings from reduced operation and maintenance costs* – with a more efficient energy concept, the building will require less energy; efficient water fixtures require less water use; with a proper waste management, the waste generated from the building's activities can be significantly reduced; and the careful selection of materials, may increase the development's durability and life (Green Plus, 2013).
- Improve the real estate company's *marketing credibility and prestige value* by stating commitment to sustainable practices.

The second group, i.e. the social benefits, focuses mainly on the occupants' well-being. Implementing green building certification solutions in the design and construction of the building, may lead to a healthier living and working environment. Some of the issues included in certification systems are (WGBC, 2013):

- *Designs for natural ventilation*
- *Availability of view out and daylight*
- *Better lighting*
- *Individual thermal control for better thermal comfort of the occupants.*

By improving the health conditions of the indoor environment, one can expect an increase of the *workplace productivity*, as well. For example, by providing better daylight on the working place the workers' productivity can be improved with *18%* and with natural ventilation (openable windows) – *with 11%*. In the same time, different studies suggest that outside view can affect *the mental and memory functions* and improve them with 10-25% (WGBC, 2013).

Furthermore, certifying a development favors the community as well - it *minimizes the stress on the local infrastructure* by introducing transport alternatives to the building; *raise awareness* about sustainable practices in the built environment; motivate other organizations and businesses by setting an example, etc. (Green Plus, 2013)

As already mentioned in the previous two chapters, the real estate sector has a significant role and influence on the environmental conditions on a global and regional level. Therefore, by addressing environmental issues as part of a project's certification, the developer implements *the precautionary principle* and reduces the overall negative impacts of the building. Among others, some of the benefits from environmental point of view are (Green Plus, 2013):

- *Preservation and support of ecosystems and biodiversity – for example, through careful site selection with limited impact on wildlife and by protecting already existing ecological aspects during the construction phase*
- *Improvement of the water and air quality in the region*
- *Reduction of the waste generated within the development and increase of the recycling rates*
- *Meeting local and global environmental goals and objectives*
- *Considerations of the Earth's limited resources and their efficient use.*

These benefits from GBCSs strongly depend upon factors such as *climate, topography, local building standards, timing, type of development (retail, office or dwellings), the owner as well as the occupants' commitment and understanding of sustainable green building concept.*

Since the beginning of the 1990s many Green Building Certification Systems have been introduced to the market, on international and regional level, integrating the above features with all advantages and disadvantages. Among others are the German DGNB (German Sustainable Building Council), the French HQE (High Quality Environmental standard), the Japanese CASBEE (Comprehensive Assessment System for Built Environment Efficiency), the Green Star certification system in Australia, etc. However, among all others two stands out – *the UK certification system BREEAM and the US – LEED.*

2.1 BREEAM

The first assessment method for sustainable buildings was introduced in 1990 in the United Kingdom (UK) by *the Building Research Establishment* (BRE) under the name *Building Research Establishment Environmental Assessment Method, or shortly BREEAM*. Over the last two decades around 425,000 buildings were certified under the BREEAM scheme and about 2,000,000 registered for assessment (BREEAM, 2014). It is internationally recognized and applied in over 60 countries, even though the biggest share of certified buildings is in the UK. It has laid the foundations for all other certification and rating systems to come afterwards.

Two of the main aims of BREEAM are to mitigate the impacts of buildings on the environment, on one hand and to stimulate demand for sustainable buildings, on the other (BRE Global Ltd., 2012).

BREEAM objectives are to encourage real estate developers to build buildings that are (BREEAM Videos, 2014):

- Healthy,
- Cost effective,
- Perform well over a longer period of time,
- Inspiring, and
- Protect environment.

This British system covers all building types from schools to hospitals, offices, retail and industrial buildings and even private homes. The various building types are organized in four major schemes (BRE Global, 2014):

- *BREEAM Communities* – “especially for communities which provide integrated working, living and recreational facilities”;
- *BREEAM New Construction (NC)* – mainly focused on the design and construction phase of a development;
- *BREEAM In-Use* – for the better management and improvement of the existing building stock;
- *BREEAM Refurbishment and Fit-Outs* – major renovations of existing buildings.

BRE recognizes the differences among different regions and gives the possibility for adapted country-specific BREEAM schemes, represented by National Scheme Operators (NSOs). This results in a better implementation of the national best practices and the better understanding of the assessment method in general.

BREEAM uses a balanced score card approach that is “supported by evidence-based science and research”. The building projects are assessed at their design and post-construction stage embracing the three aspects of sustainability in the following category groups (BRE Global, 2014):

- *Management* – commissioning, site management, procurement and management policy;
- *Health and Wellbeing* – indoor and external quality aspects (air quality, lighting, noise, etc.);
- *Energy* – operational energy and the related emissions of carbon dioxide (CO_2);
- *Transport* – location related factors and transport-related CO_2 ;
- *Water* – consumption and efficiency;
- *Materials* – building materials impacts throughout their life-cycle (for example, related CO_2 emissions);
- *Waste* – resource efficiency during the construction and operation of the building, as well as waste minimization;
- *Land Use and Ecology* – site selection and the building footprint;
- *Pollution* – associated outdoor water and air pollution.

There is also an additional category group “*Innovation*” that rewards projects with additional credit points for performance above the credit requirements. For the purpose of this study this credit category is omitted.

There are around 150 credits available for the assessment throughout all different BREEAM schemes. Depending on the project type, as well as certification goals, an individual scorecard is prepared for each project. The achieved credits from each category group are multiplied by an environmental weighting factor that represents the relative importance of each section (BRE Global, 2014). The Table 1 presents the environmental weightings applied, which are based on a consensus of research different groups of actors with different decision-making backgound ranging from government, lobbyists to material suppliers.

Table 1 BREEAM Environmental Section Weighting

Environmental Section	Weighting
Management	**12%**
Health and Wellbeing	**15%**
Energy	**19%**
Transport	**8%**
Water	**6%**
Materials	**12.5%**
Waste	**7.5%**
Land Use and Ecology	**10%**
Pollution	**10%**
Total	**100%**
Innovation (additional)	**10%**

Source: BRE Global Ltd., 2012, Section 3.0

Once the section credit scores are individually weighted, the sum of all categories gives the overall score for the building and assigns one of the following certification levels:

Figure 3 BREEAM Certification Levels

Source: ENERGO Group, 2015

The certification level, that a project achieves, gives a clear message to real estate buyers, future occupants, practitioners, and designers about the extend to which green building sustainable practices are integrated into the design, construction or refurbishment of the project.

One should also keep in mind, that even though there is not a big difference between the certification levels, in terms of percentage, the higher the rating score an owner wants to persue, the higher the system requirements and initial investments are.

As previoulsy mentioned, BREEAM has been the base for many other GBCSs with its methodoloy, scope and ideology. One of this systems is the American Leadership in Energy and Environmental Design certification system, or better known as LEED.

2.2 LEED

In 1993 the U.S. Green Building Council (USGBC) has been formed and a year later a working group has been established, in order to evaluate and rate the relations between the built environment and the sustainability impacts that it imposes. The committee consisted of actors with different backgrounds, level of expertise and interests, such as building owners, architects, lawyers, environmentalists and industry representatives (USGBC, 2009).

The first version of LEED lauched in August 1998 has been improved and updated continuously to the most current version – LEED v4. The schemes, rating and credit categories presented below reffer to the LEED v3 (2009) version, as this version was considered for the reference projects in this thesis.

Up to this moment there are more than 69 000 LEED projects in around 150 countries. Even though LEED certification systems are mostly based on the American norms, standards and market needs, approximately 44% of all certified projects are outside the USA. As of December 2016, the top 10 countries with registered or certified projects under LEED system requirements, outside the U.S., are (USGBC, 2016):

1. China
2. Canada
3. India
4. Brazil - developers planning new commercial projects
5. Republic of Korea
6. Taiwan
7. Germany
8. Turkey
9. Sweden
10. United Arab Emirates – main focus on green institutional buildings

Of course, this global interest is already addressed in the latest two LEED versions with the introduction of the "*Alternative Compliance Paths*", giving the opportunity for projects outside the U.S. to fulfill the credit requirements based on the standards of the country in question.

No matter in which region a project is being developed, LEED objectives aim to promote built environment that is (USGBC, 2009):

- Healthy
- Durable
- Affordable and implement environmental sound practice in building design and construction.

In order to meet system's goals, USGBC distinguishes between the buildings typology, project scope and sectors by introducing specific rating systems. For example, LEED 2009 version differentiates between the following certification building types (USGBC, 2009):

- *LEED for Core & Shell* – project developments that are undergoing major renovations;
- *LEED for New Construction* – newly constructed buildings;
- *LEED for Schools;*
- *LEED for Neighborhood Development;*
- *LEED for Retail;*
- *LEED for Healthcare;*
- *LEED for Homes;*
- *LEED for Commercial Interiors.*

Similarly to the BREEAM system, LEED rating systems address the environmental performance of a project based on its whole life-cycle, rather than focusing only on one of its development stages.

The USGBC recognizes five major impact categories under which common measures for preservation of natural goods, mitigation of negative impacts on the environment and human health, and economic aspects are taken into consideration. Therefore, LEED certification systems are divided into credit categories described below (USGBC , 2012-2015):

- *Sustainable Sites* – credit requirements address strategies that reduce the impact of the projects on water resources and ecosystems;
- *Water Efficiency* – encourage better utilization of water in the buildings' operations inside and out, and promoting practices that reduce the consumption of potable water within the development;
- *Energy & Atmosphere* – promoting innovative energy management strategies, in order to improve the building's overall energy performance;
- *Materials and Resources* – addresses the scarcity and limits of the natural resources' stocks by incorporation of sustainable building materials and waste management measures to reduce the amount of waste generated during the construction and operation phases;

- *Indoor Environmental Quality* – focuses on the indoor air quality and access of daylight, as to improve the indoor environment for the building's occupants.

In addition to the five major credit categories, the LEED system rewards efforts that exceed the primary credit requirements with additional credit points for their exemplary level of performance, organizing them in two groups:

- *Innovation and Design Process* – including design tools and measures, sustainable business practices, etc.;
- *Regional Priority Credits* – allowing projects to earn additional credit points based on regional environmental priorities.

Correspondingly to the *BREEAM "Innovation" credits*, the later two groups are omitted in the further discussions of this study, as they can be quite subjective (randomly chosen from the assessor certifying the project) and strongly regional dependent.

LEED 2009 Core & Shell Rating Catalogue comprises of 51-71 credits available for certification. The number of credits depends on the project's type – school, retail, etc. Opposite to the BREEAM credits, LEED system has minimum credit requirements - that do not contribute to the final score - which must be fulfilled in order to certify a project. The minimum credit requirements and their role in the overall certification project are discussed in the next chapter.

However, LEED also assigns to the credit categories weights that are "based on the potential environmental impacts and human benefits of each credit" within the respective impact categories – GHG emissions, toxins and carcinogens, fossil fuel use, indoor environmental conditions, water and air pollutants, etc. (USGBC, 2009). Aiming to provide a comprehensive and sound base for the weighting of the single credits, LEED 2009 uses the *U.S. Environmental Protection Agency's TRACI* environmental impact categories and the weightings established by the *National Institute of Standars and Technology (NISI)* (USGBC, 2009). Combined, these two reference benchmarks develop the LEED 2009 Core & Shell system's weighting in Table 2:

Table 2 LEED 2009 Environmental Weightings

Credit Impact Category	Available Credit Points (Weightings)
Sustainable Sites (SS)	**28**
Water Efficiency (WE)	**10**
Energy & Atmosphere (EA)	**37**
Materials and Resources (MR)	**13**
Indoor Environmental Quality (IEQ)	**12**
Total	**100**
Innovation and Design Process (ID) (additional)	**6**
Regional Priority Credits (RP) (additional)	**4**

Source: USGBC, 2009.

As it can be seen from Table 2, instead of percentage attached to each credit category, the total category score is rather represented in points that sum up together to 100 (without the two additional categories). Thus the system gives real estate developers the opportunity to certify their assets with the highest certification level without exceeding the necessary input required for fulfilling the aims of the credits, i.e. without an obligatory exemplary performance needed for the two additional categories.

Another difference to the BREEAM weightings and credit points' allocation is that LEED credits parameters ensures that each credit is valued with at least one point, is a positive, and a whole number. There are no project specific scorecards depending on the location of the project but the credit points available may vary for the different rating systems and type of development – whether the project is being newly constructed or undergoes major renovation, or a project evaluated under the LEED 2009 for Existing Buildings, and so on.

The total score that a development achieves by meeting the system's requirements, awards the project with the desired certification level. In contrast to the BREEAM certification levels, LEED distinguishes only between four certification labels – *Basic, Silver, Gold and Platinum Certification*. The Figure 4 illustrates the points' threshold needed, so as to receive the one or other certification label.

Figure 4 LEED Certification Levels

Source: (Glick, 2013)

The lowest achievement with the LEED rating system is the "*Certified*" Label, i.e. *"Basic Certification",* and the highest is the "*Platinum*" rewarded from 80 points upward. Analogue to the BREEAM Certification Levels, a higher rating system score not only gives a clear signal for the developer's commitment to the green building sustainability, but also represents higher building's performance in terms of environmental concerns, economic savings and social benefits.

Even though both systems share quite similar objectives and approaches, there are still differences between the number of credit categories, minimum credit requirements, credits' scopes, credits' organization into the various categories, and so on.

In order to illustrate these differences in a more comprehensive manner, two different projects have been used as examples. The baseline scenario, or Scenario 0, in this thesis, has been developed on projects' performances and the original systems' requirements.

2.3 Baseline Scenario 0 - Introduction of the reference projects

As previously mentioned, both systems give the opportunity to choose to what extend the investors, developers and designers integrate sustainable practices in a project. Depending on the motivation and preferences for certification - whether for marketing reasons or for the better quality of their development, to raise their properties value or to address a specific environmental issue - real estate decision-makers can choose between different systems. For the purpose of this study, the practitioners have chosen LEED and BREEAM certification systems, as base for a pre-assessment of the projects in question. The projects themselves have been selected according to similarities in their location, size, building's use, etc.

Table 3 presents a short summary of the two reference projects. This table and the benchmark *Scenario 0* are based upon the pre-assessment reports from *Alpha Energy&Environment Austria GmbH.*

Table 3 Comparison Reference Case Study Projects

	Project A	Project B
Location	Central location	Location nearby the city inner circle
Area	ca. 21 000 m_2	ca. 28 000 m_2
Use	Office spaces, Shops, Apartments	Office spaces, Shops
Energy supply	District heating	Geothermal, District heating, Photovoltaic
Heating	District heating	District heating
Cooling	District cooling	District cooling
Ventilation	Natural and mechanical	Natural and mechanical
Water	Public water supply	Public water supply
Transport infrastructure	Excellent*	Very good**
Type of project	Major Renovation	New Construction

Source: (ALPHA Energy&Environment Austria GmbH, 2013)©

* Excellent = bus and tram connections within a 500 m radius, more than one possibility for an underground.
** Very good = bus and tram public transport available and one possibility for an underground connection.

As it can be seen from Table 3, these two projects are very similar with some slight differences in their location, size and type of project - construction or renovation. In this case the project's type will not influence the implementation of the different scenarios, as both LEED and BREEAM do not differentiate between "Major Renovations" and "New Construction". The first is a process of full reconstruction of an existing development and is related with substitution of the HVAC (Heating, Ventilation, and Air Conditioning) system with up-to-date equipment, replacement of the old windows, substitution of the water pipes systems, additional strengthening of the foundations and the walls (including insulation), etc.

After undergoing the pre-assessment under both LEED and BREEAM, the certification levels that can be gained for both projects in each system individually have been determined. These levels are in terms of the initial construction or refurbishment plans and are usually associated with no further costs for the contractor, as long as no major deviations are undertaken along the construction or refurbishment process. For instance, Project A can achieve under the LEED®Core&Shell 2009 version "Silver" Certificate. The same project can score a

"Very Good" Certificate with the BREEAM International New Construction 2013. Similar to Project A, Project B is just beneath the bar for a “Very Good” certificate with BREEAM International New Construction 2013 but it can be certified with LEED®Core&Shell 2009 in "Gold" (ALPHA Energy&Environment Austria GmbH, 2013). However, only credits identified at the pre-check, of the two reference projects, as credits with potential to contribute to the final certification goal, have been included into the category groups and the different scenarios. For further detailed information on the performance of the two projects, the credits achieved and the certification levels possible under the two systems please refer to Appendix 0. There the two systems are presented in their original structure and in terms of the reference projects.

In order to develop other scenarios for this study, further investigation of the relationship between the real estate sector and the environment is needed. The better understanding of how each of them impacts the other is of crucial importance.

3 Development of the Methodology

As simple as it sounds, comparing the two systems is challenging. Even though, both systems emphasize on similar environmental impact categories, the requirements behind can differ in their scope. In order to compare the two systems, the focus of this thesis is on the weighting and issue at a hand of the different credit categories rather than their scope and requirements.

The two Green Building Certification Systems, introduced in the previous chapter, are based on the idea of sustainability and its implementation through the whole life-cycle of a building - from the moment raw materials are extracted through its eventual demolition. Nevertheless, the systems are developed upon different environmental impact categories with credits addressing mostly buildings' negative effects on our ecosystems. Every single category, as well as the credits themselves, is weighted depending on the severity of the impact they impose to nature according to the actors involved of the certification systems' scope definitions.

In order to test the sensitivity of the systems' weights on the overall results and find out what do they stand for in terms of sustainability practices, different scenarios with alternative weightings will be presented. The scenarios are carefully developed to take into account the most relevant threats of buildings toward the environment and vice versa, as well as to occupants' health and wellbeing.

The *baseline scenario (Scenario 0)* represents the systems in their original categories and credits structure - initial points available, initial weighting behind the systems, etc.

The *first scenario (Scenario A)* takes into consideration the outcomes from different studies on the topic of the real estate sector's relation with the environment and more precisely the impacts of this sector on the environment. Based on *Chapter3.1.1 Buildings 'Environmental Impacts* an alternative approach can be introduced into LEED and BREEAM, to address the most important ecological factors on European level. Because of this scenario, the systems' weightings shift their focus to the environmental aspects within the certification, rather than the economic or social ones.

Opposite to Scenario A, *Scenario B* gives the opportunity to view the systems from an environmental perspective and investigate the environmental impacts on the real estate sector by analyzing different studies focusing on this issue. *Chapter Environmental Impact on* introduced several environmental factors that can greatly influence the price and the overall performance of a development.

The last alternative, *Scenario C,* has been developed from a practitioner perspective, giving two options. This serves as an example that quite often there is a difference between the literature (the scientific point of view) and a practitioner's point of view (an auditor), in terms of one's focus and preferences.

All these scenarios, with the help of the reference projects, can send a signal to investors, designers, developers, certification professionals, on what the systems emphasize the most. The four scenarios will be implemented on the projects, as to create conditions as close to the normal state of the systems as possible. With the help of different multi-criteria decision-making methods and other scientific tools Scenarios A to Scenarios C will receive new weightings accordingly. The aim is to present two different outcomes with the intention of testing the initial hypothesis of this paper and giving comprehensive suggestions on how to choose the most suitable GBSC for a project. One of the outcomes of this study will be the certification level that can be achieved within the scenarios, in respect to the reference projects. The second will investigate in depth chosen credit categories and their performance within the boundaries of the study. Figure 5 sketches the main methodological aspects of the paper.

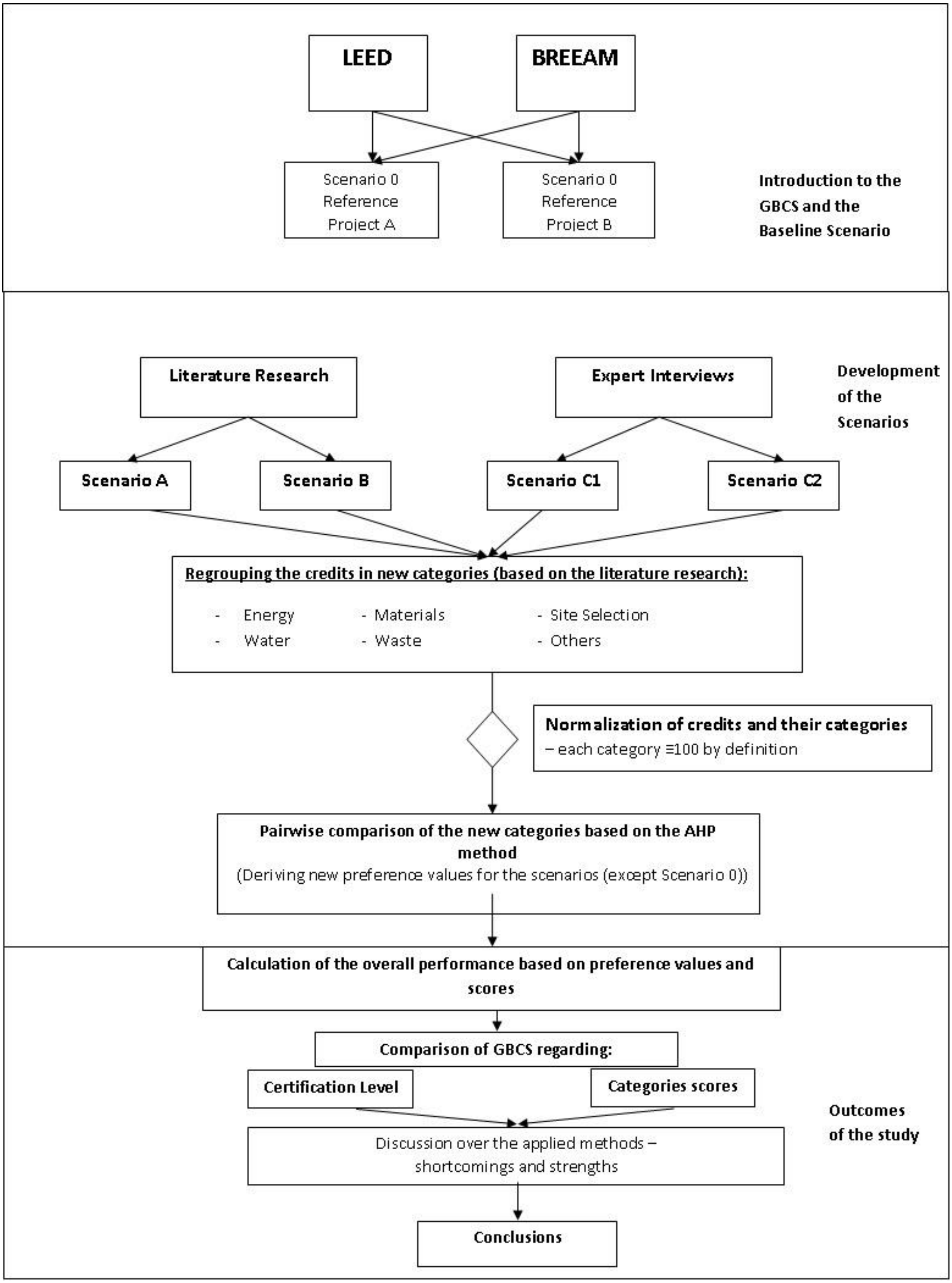


Figure 5 Applied methodology in this study

3.1 The Real Estate Sector and the environment

In order to make sound decision investors, real estate managers, designers and developers should keep in mind not only the economic and social factors, but also the environmental effects related with a development. As a result, they should consider the different environmental impacts that projects impose, as well as the environmental impacts that are imposed to these projects. This can be accomplished by informing themselves or just turning to an expert in this field. Only once the interaction between buildings and environment is fully understood, there is a possibility for a reasonable choice of the extent to which one wants to integrate sustainability patterns into a development.

3.1.1 Buildings 'Environmental Impacts

While the most attention of real estate actors and building regulations is focused on the energy consumption and reduction, there are much more environmental impacts that need attention.

According to the *European Commission (EC)* and their appeal for discussion on reducing environmental effects, buildings account for:

- *42%* of final energy consumption (during their use phase)
- *35%* of GHG emissions (during use phase)
- *50%* of all extracted materials are used in buildings (construction and use)
- *30%* of water consumption (construction and use phase)
- *30%* of generated waste (during construction, demolition and renovation) (EC, 2013).

Even though, these numbers may be well-known to the regulators, they still come quite often as a shock to the practitioners. Therefore, better understanding of each one individually, is further introduced in the next pages.

<u>Air and Atmosphere</u>

About a recent report from the *Buildings Performance Institute Europe (BPIE)*, there is an increase of the energy use in the last 20 years and this trend is likely to continue (BPIE, 2011). As already mentioned, the energy consumption in the real estate sector is an essential part of the total consumption on European level, with *5-10%* of the total energy consumption utilized for the production of construction materials (EC, 2014). Additionally, differentiation between the energy consumption within the building sector can be made. The residential buildings are the biggest energy consumer with its *68%*. The most common uses of energy in households are: "heating, cooling, hot water, cooking and appliances" (BPIE, 2011). The same is also true for non-residential buildings, especially office spaces, where the heating, cooling and air conditioning demands are the biggest energy consumers.

The most recognized environmental burden from the production of energy undoubtedly is the released CO_2 emissions which are one of the main contributors to climate change. On a European level, buildings account for about *36%* of the CO_2 emissions, where the mean value is *54* $kgCO_2/m^2$. This value may vary from *5-120* $kgCO_2/m^2$ across the European national values. Thus, for example, Norway has the lowest CO_2 emission level with about *3* $kgCO_2/m^2$ and Ireland has more than *120* $kgCO_2/m^2$. Austria is within the 10 lowest CO_2 emitters per floor area and Germany is on the 17th place (BPIE, 2011).

Similar situation can be observed also in the U.S., where the energy consumption of buildings, as well as the related CO_2 emissions, account for approximately 39% from the total energy consumed (US EPA, 2009).

<u>Soil</u>

Next to the atmospheric impacts and their negative effects, buildings' whole life-cycle affects also other vital natural resources, such as the soil cover. Soil has essential functions for life's balance, such as production of food, water infiltration and cleaning processes, important nutrients to soil organisms, protection against flooding, etc. One of the biggest threats to soil is its compaction. As the population on Earth increases, so does the soil sealing. In urban areas, it results in construction of buildings (mostly housing) and the corresponding infrastructure. The negative effect of this compaction is enhanced using impermeable materials such as concrete, stone, asphalt, etc.

One of the biggest environmental consequences of surface covering in the cities is the so called *"heat island effect".* It causes an increase in energy demand, GHG and air pollution, different health-related illnesses and mortality. The heat island effect is one of the factors that regulate air temperature in urban areas. The next figure shows the correlation between the surface compaction and the temperature in the city of Budapest (EEA, 2014):

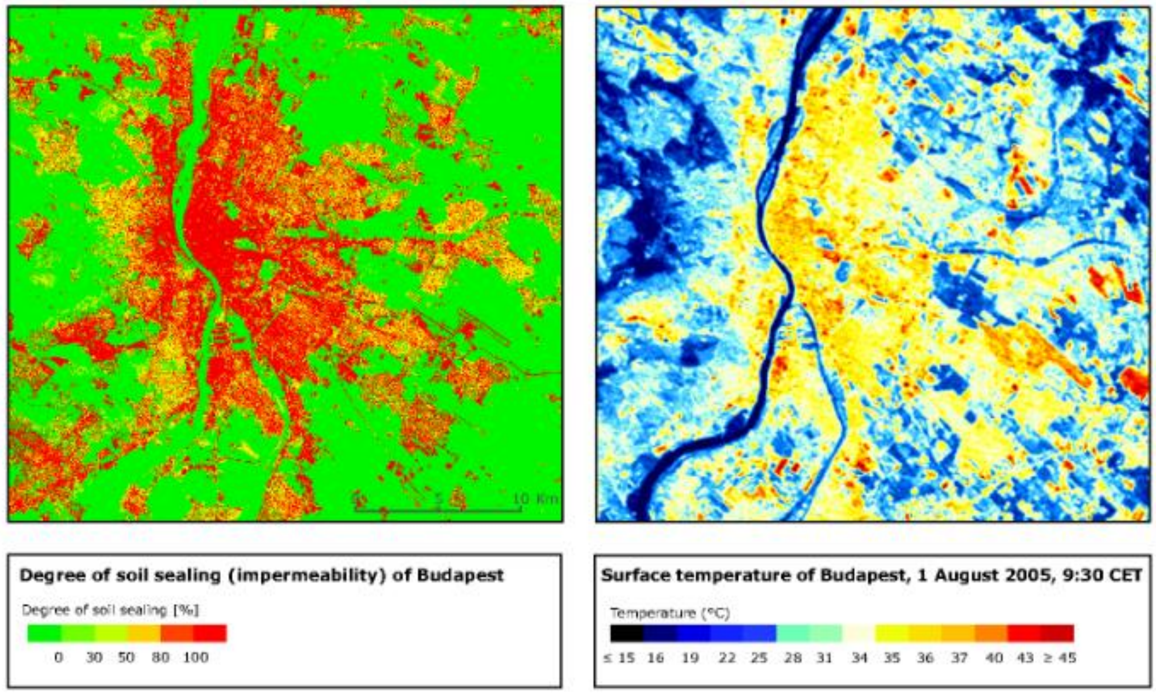


Figure 6 Comparing the degree of soil sealing and the surface temperature in Budapest, Hungary

The two maps illustrate that a higher percentage of soil sealing, leads to a higher air temperature in parts of the city where there are compacted areas, in contrast to greener areas. This creates prerequisites for a system that is much more vulnerable to the climate change and puts at risk the health of the more sensitive population - children, elderly people, people with heart and chronic diseases, for example.

Finally, covering the surface results in lowering the water potential for infiltration into the soil and therefore to higher risks of water run-off. The second can result in river flooding, river pollution (through the transport of pollutants, chemicals, dust, etc.), and thus lead to life losses, as well as economic ones (EEA, 2014).

To protect the still non-compacted soil, certain actions should be taken. Some solutions can be (EEA, 2014):

- The reduction of soil sealing where not needed (parts of public places, parking lots, brownfields, etc.)

- Maximize unsealed and green areas by complementing the covered surfaces with street trees, green walls and roofs.

Protecting the air and soil resources consequently helps the protection of other basic natural components, such as water.

Water

Among others, water scarcity is a topic that receives a lot of attention when talking about environmental challenges. However, most of the freshwater reserves are stocked in glaciers and ice caps and therefore are not "readily accessible for human use" (UNEP, 2008). Consequently, the supply of freshwater for the needs of the Earth's population mostly depends on groundwater - more than *90%* of the freshwater utilized worldwide. Other supplies of this natural resource are rivers, wetlands, reservoirs and lakes.

As previously mentioned, the compaction of soil surface can result into serious risks for the groundwater supply and its quality, rivers' ecological conditions, as well as the water cycle in general. In addition, *one third* of all freshwater available in Europe is utilized from the building sector (EC, 2014). All together these calls for more actions for the protection of this scarce resource and for its reuse - for example, rain water collection and its utilization for pot water. This and other sustainable measures, such as raising awareness and changing occupants' consumption patterns, and installation of water efficient faucets, can be considered when taking decisions on how to mitigate and enhance the water efficiency within a development.

In the same time, large quantities of water resources are also utilized in the agricultural and industrial sector (for extraction of materials, for example).

Materials

Raw materials also count to the scarce resources on our planet, due to their overexploitation during the industrial revolution. The European Union is already taking important steps towards more sustainable resource exploitation in the building sector. This comes as no surprise, as approximately *50%* of the extracted materials in Europe are used for the construction and use of buildings (UNEP, 2008). There are two main alternatives to raw materials - recycling of materials or their reuse. In order these two options to be conducted in a sound manner, there is a need of efficient local, regional and national recycling system in place. These are influenced by factors, such as: "the length of transport distances to recycling sites, achieving the necessary level of purity of the recycled materials and recycling and production processes" (European Commission, 2014).

Recycling and reuse of materials also addresses the need of waste diversion from landfills which by 2030 EU's waste objectives should reach over 70% (European Commission, 2014).

After analyzing these issues in the context of real estate sector’s impact on the environment, the author of the paper will use the results to develop Scenario A.

3.1.2 Environmental Impact on the Real Estate Sector

The influence of the real estate sector on the environment is a topic that one always come along when investigating this relationship. However, there is also the need to understand how the environment sets limits or favors a development. The purpose of this chapter is to review the different natural factors that can influence the decision of a real estate developer where to construct its building; whether there is necessity for additional investment in terms of the envelope of the building, for example; or the choice of materials; the addition of more cost-effective lighting in the building, where due to limitation of daylight, and integrating of HVAC with high energy efficiency, etc.

The dependency of the human activities on the stock of natural resources, such as soil, water, atmosphere and materials, is irrefutable. The other is also true – the environmental conditions, strongly depends on the human utilization and exploitation of these resources. This makes it quite difficult to separate the one from the other. Very often the relationship and search for balance between the two, is a main topic in climate change debates. The later, focuses on the natural resources (soil, water, air, materials, etc.) and their protection.

To enhance the objectivity and completeness of the current study, and in the same time assist developers in making a sound decision of where and how to plan a building, the environmental influences on the real estate sector are reviewed, based on literature research and its analysis from the author of the thesis.

Soil/Site Selection

As the land use in Europe has drastically changed over the past century, the soil protection needs more attention, if the countries want to reach their sustainability goals. According to the European Environmental Agency *“Land is finite resource and the way it is used is one of the principal drivers of environmental change, with significant impacts on quality of life and ecosystems as well as on the management of infrastructure”* (EEA, 2013).

As an old-time real estate cliché is suggesting, there are three important value determinants when considering the value of a building: *"location, location, and location"* (Carr, 2003).The surface, on which a building is being constructed, can be seen as one of the biggest challenges and investments - whether it is non-developed site (greenfield), whether it is already existing building, or it is a site that need remediation as a result of soil contamination (brownfield), etc.

Only 4% of the soil cover in Europe is compacted with artificial surfaces, mainly buildings and infrastructure. Most of them are concentrated in urban areas, especially in and around big cities. This inevitably leads to “heat island effect” in these areas. Therefore, increasing the regulation efforts in these areas and the preservation of greenfields is necessary. Thus, the compaction of the soil and the different regulation tools make this natural resource a limited one, especially in developed regions. This stress on the soil surface, among others, is the driving force behind regional initiatives in some European regions, as there are still no agreed upon national regulations to address the issue.

Different initiatives, for example the *Urban Development Plan for the city of Vienna*, seek alternatives to the greenfields in brownfield redevelopment.

Brownfields have no common definition across Europe but in most of the cases they carry the following characteristics (Siebielec (ed.), 2012):

- Abandoned sites
- Often but not always contaminated
- Require reclamation/revitalization
- Relict of industry, construction, agriculture, military or anthropogenic activities.

Whether a site is contaminated or not, can greatly influence the readiness of investors to buy and develop a land. In the case of contamination, not only the initial examination of the soil properties plays a crucial role for the level of investment, but also the future remediation measures should be considered, as they usually result in extra costs. Furthermore, the property's value can be significantly reduced as result of its status as a brownfield, in comparison to greenfield, which may play a significant and rather negative role for developers' decision-making.

Another example of the soil surface as a limitation for real estate developers is the city of Salzburg and its declaration *"GeschützesGrünland",* which aims *"to protect approx. 3 500 ha of greenfield land"* (Siebielec (ed.), 2012). With issuing the declaration, the city restricts the construction on greenfields. Although there are certain exceptions, permission is only possible for special community benefits and only in the case that other types of land cannot serve the city's interests and needs. However, examination of alternatives, such as brownfields is mandatory. Indeed, such types of initiatives and land use management tools will put even more stress on the real estate sector in the coming years and a readjustment in their investment and development patterns will be inevitable.

In the future real estate trends', the site selection will play even a greater role with the upcoming awareness and focus on the preservation of undeveloped land. The search for alternatives will be even more appealing.

The site selection further strongly depends on the type of building and its use. It makes a great difference, if one develops a residential, industrial, commercial or building for recreational purposes. The latest demands higher degree of greenery within the site, compared to industrial ones, for example (Cellmer, Senetra, & Szczepanska, 2012). As a result, taking a closer look to the environmental quality of the site, such as the topography, the drainage and infiltration capacity of the soil, should be considered. The same is also true when considering the environmental status of a certain site, i.e. whether it is part of natural protected area or an important corridor for migration of wild animals, for example. These can set additional limitations for developers.

Water

As already discussed, soil compaction affects not only the soil characteristics, but also the water ability to infiltrate the soil, regenerate and maintain the hydrological cycle at local, as well as global level.

Water is one of the most important resources for the society, the ecosystems and the economy. This resource influences and supports our existence not only by providing drinking water and irrigation water for crops but also plays a significant role in the operation of each building. It is used for cooling purposes in power plants, as source for energy, heating purposes, toilet flushing, landscape irrigation, etc. Considering these examples, one can conclude that the availability and quality of water can have a great impact on the daily operations of buildings, or in other words we depend on water.

For example, the agricultural sector is responsible for 44% of the abstracted water in Europe, followed by the industrial and energy sectors (for cooling in power plants) with 40%, and the domestic sector which utilizes about 15% from the total amount (EEA, 2008).

The increased water demand for human activities is not the only challenge for the decision-makers (e.g. politicians and scientists). Another factor that influences the decreasing amount of freshwater resources is the long and frequent periods of droughts in many European regions. This puts not only the ecosystems under additional pressure, but the water demand for social and economic activities, as well. Among others, this calls for the attention of the public and governments, in order to avoid any further negative impacts, such as: *"water supply problems, shortages and deterioration of quality, intrusion of saline water in groundwater bodies and increased pollution of receiving water bodies, and drops in groundwater levels"* (EEA, 2008). This may result in enormous economic loses which affect mostly the end users, but also property owners or the tax-payers.

According to different climate change scenarios the trend of summer droughts and decreased rainfalls throughout all four seasons, together with the higher temperatures, will continue the increasing water demand tendency in the future (EEA, 2008). This will set some limitations for water usage that can affect the water practices in building operations.

Therefore, certain precautionary measures should be introduced, to mitigate and assure sustainable water resources for the coming generations. This is one of the major objectives of the *European Water Framework Directive*. This regulation has obliged the Member States of the European Union (EU) to implement different monetary and other water conservation techniques. One economic instrument is the water pricing. The country of Estonia, for example, after introducing the water pricing has achieved up to 50% water use reduction over a period of 15 years (EEA, 2008). However, one of the main requirements for the implementation of water pricing successfully is the metering of the water use. The later instrument has the same effect on the users as the water pricing itself. Together with other tools, such as *"water re-use and recycling, increased efficiency of domestic, agricultural and industrial water use and water saving campaigns supported by public education programmes"* (EEA, 2008), these two precautionary measures can avoid future stress on the water resources and unfavourable pressure on the ecosystems, social and economic activities. In the same time, all new regulations and techniques imposes new additional costs and considerations that every real estate developer should consider when planning a building and continue this consideration in the its operation.

However, if the water resource problems exacerbate, we should expect restricting instruments that will force new patterns of water consumption and will further influence economically human activities and daily operations of the building stock.

Materials

The construction sector together with others also depends on global economic and social factors. It strongly depends on the global market conditions for raw materials (RMs) and their availability, distribution, production, supply and demand. The next paragraphs present some of the most recent developments on the respective market.

The raw materials' management is not a new topic in the scientific and political agendas. Since papers, such as *"The Economics of Exhaustible Resources"* in 1931 and the 1972 *"Limits of Growth"*, the discussions about raw materials' scarcity, over-exploitation, production and demand, have evolved. Other factors like "supply concentration, governance of producing countries and material's substitutability" (JRC of the European Commission , 2013), have emerged in the decision-making processes in the past decade.

None of the above would be an issue, if the raw materials' availability was not under stress. The increased pressure on these natural goods, according to many practitioners, is not only the result of their limited quantity from geological point of view, but rather the uneven distribution among the world raw materials stocks and reserves (Raw Materials Supply Group by the EC, 2010). This can be also confirmed from the diagrams below where the reserves of non-renewable resources, such as coal, oil, copper and iron, and the major regions of extraction are illustrated:

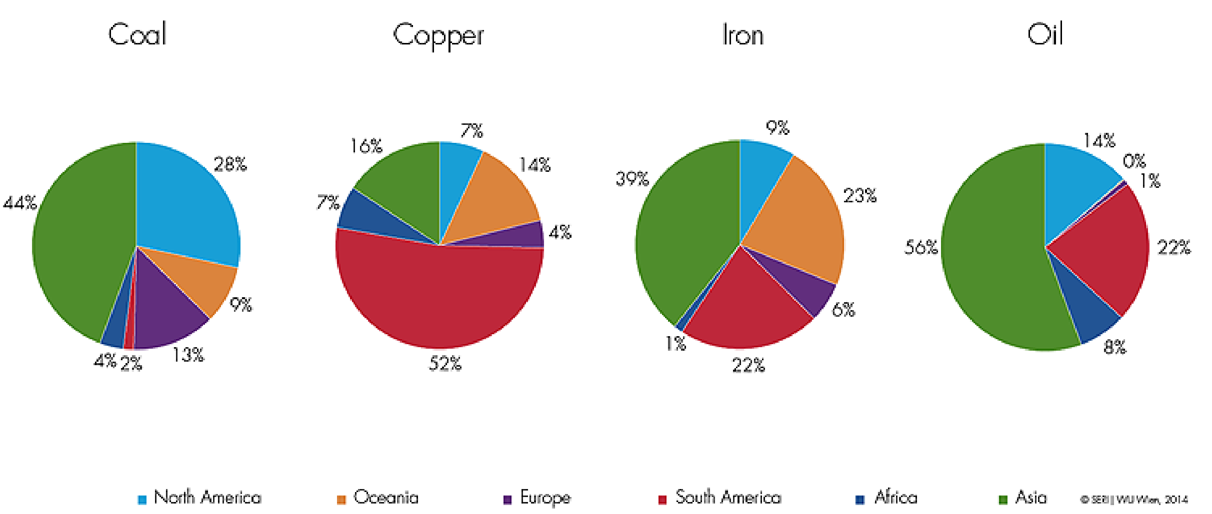


Figure 7 Non-Renewable Reserves and their Distribution Worldwide

Source: (SERI and WU Vienna, 2014)

For instance, more than 50% of the oil stocks are available in Asia, i.e. the Middle East and 44% of the total world reserves of coal - in China. As seen above, the European raw materials stocks are quite limited which suggests that the countries on the old continent strongly depend on importation of primary resources.

Together with changes in the patterns of supply and demand in the past decades, due to growth in the world's population, higher prices and shifts on the market have been observed. Major factors that contribute to this shift are "the emerging economies and the diffusion of new technologies" (JRC of the European Commission , 2013). In many cases, these countries (such as China, Brazil, etc.) account to the biggest producers of raw materials, as they possess the highest concentrations worldwide. Nevertheless, this leads to shift of power between the developed and developing countries, as the emerging countries often use their abundance of raw materials "as a strategic political tool" (JRC of the European Commission , 2013), i.e. "raw materials nationalism" (Roberts, 2015). In such case, the country in question preserves the raw resources only for its own use by introducing restrictions, for example export quotas, in order to force foreign investors to produce on their territory and in the same time reducing the economic competitiveness of countries strongly dependent on the imports of raw materials (mostly developed countries - the EU member states and the USA among others) (Roberts, 2015). This raised the concerns of the importing countries and different course of actions are being considered to decrease this dependency.

Important steps towards diminishing the influence of the imported raw materials on the economy, are researching for alternatives. One possibility is the use of secondary raw materials through higher recycling rates. These measures cannot fully replace the need for imports or totally secure the supply, but can at least decrease the pressure for raw materials in Europe.

In order to address these past concerns about the supply and availability of raw materials, the European Union identified 20 Critical Raw Materials (CRMs). This group is based on recognizing the importance of reserves distribution among few countries, rather than the scarcity of resources as a whole. Among others, the low substitutability and the low recycling rates of the resources is taken into account. Some of the main materials within that list are: Antimony, Beryllium, Cobalt, Magnesium, Niobium, Rare Earth, and PGMs (Platinum Group Metals).

For instance, *Beryllium*, which extraction originates to 99% in USA and China (Raw Materials Supply Group by the EC, 2010, p.36) is used in the construction industry for structural elements that have to be light but at the same time are "exposed to great forces" (Wulz, 2014). Also, the element Niobium (produced mostly in Brazil) is mainly utilized for the production of construction steel. As powerful bond for the production of diamond tools and carbide, Cobalt (main stocks in the Democratic Republic of Congo) is used in the metal mining, cutting, and drilling activities, as well as in the construction sector (Wulz, 2014).

If one considers the above described situation from developers' perspective and how it affects the construction sector, one should keep in mind that about 40-50 % of all materials present at the global market are used for the manufacturing of building components and products (UNEP, 2014).

However, Europe has sufficient stocks of construction minerals, such as crushed natural stone, clay, sand, gypsum, etc. For example, the EU is the world's largest manufacturer of mined gypsum with 25% of the total share and about 35% of the global natural stone production. These aggregates are essential for the maintenance and refurbishment of existing buildings and for the construction of new ones (EC. Enterprise and Industry, 2013).

To secure the supply of important raw resources for the construction business, further efforts have to be taken as to find substitutes and increase the recycling rate of building's demolition and construction waste which today results in 40% (UNEP, 2014). This strongly relies on the further development of raw materials utilization and efficiency in "recovering scraps, properly managing the products' end-of-life" (JRC of the European Commission , 2013, p. 14) and exploring the undiscovered deposits through mining and innovative technologies. Producing by-products as "secondary aggregates" and reusing construction waste as "recycled aggregates", can once more relieve the pressure on primary raw materials in the future.

Furthermore, the proper waste management can help not only to reach different national objectives and goals, avoid the extraction of raw materials, but it can also decrease the operational costs of a building.

Still, these measures will not be able to fully replace the need for imports and secure the supply of raw materials.

Finally, we should also acknowledge that the availability of raw resources, especially on the European market, is further restricted with the increasing environmental awareness. For example, the secure supply of primary materials is essential for the European Union from economical point of view on one side, but also quite crucial for achieving the objectives of the *“European environmental policy with respect to a low carbon economy, mitigation of climate change and energy efficient society”* (JRC of the European Commission , 2013). These European regulations extend further to countries outside the EU which cannot provide transparency and do not share the same environmental goals.

All these obstacles impose additional burden to the construction sector, e.g. the energy sector, and the balance within the ecological systems. This can further “feed” the continuing climatic changes on global level.

<u>Air and Atmosphere</u>

The scarcity of resources (soil, water and materials) and the ongoing climate change, pose significant stress on the real estate sector. This is also valid considering the energy demand of a building.

The climate change is one of the most important factors for a shift in the energy demand in this sector. Of course, these positive (decreasing electricity use) or negative (increasing energy demand) trends are unevenly distributed among the different development sectors and are regionally dependent. This is especially true when considering the seasonal differences in terms of air temperature. For example, in the summer months the southern European regions face higher temperature and increased electricity demand for buildings’ cooling purposes, which results in higher property management costs. According to the *ClimateCost Study’s* estimations, additional cost up to *“EUR 30 billion/year in the EU-27 by 2050, rising to EUR 109 billion/year by 2100”* (EEA Report , 2012, p.235), can be expected.

On the other hand, quite the opposite effect is observed in the northern parts of Europe. These countries take advantage of milder winter and lower electricity use for heating purposes. The observation data shows that *“the number of heating degree days has decreased by an average of 16/year since 1980”* (EEA Report , 2012, p.201). This leads to benefits for cooling activities as opposed to the losses in the South.

Nevertheless, the continuous rise of the air temperature and further changes in the rainfall patterns (droughts, storms, etc.) could affect also the energy supply. For instance, in summer the quantity of water for the energy generation from hydro-power may drastically decrease. By such circumstances, the conventional energy generators may face the unavailability of water for cooling purposes for the thermal power generations (EEA Report , 2012, p.201).

The future impacts of climate change on buildings' energy demand, even though sometimes beneficial, will be mostly negative. The energy prices and consumption will continue strongly to depend on geographic factors. Different actions, to mitigate these impacts, will put even more stress to the current energy market and will force changes in the energy supply and demand patterns. With these prognoses for the environmental changes, the end-user will be affected the most, i.e. by increasing or decreasing energy prices.

The four major factors presented in this chapter affect not only the public and developers financially, but they will have tremendous effects on public's health (e.g. air quality), the quality of developments one lives or works in, as well as the investors' decision-making.

The literature reviewed and analysis of the environmental restrictions influence on the real estate sector, the outcomes build up Scenario B.

3.2 Development of the scenarios

As previously mentioned, there are many factors influencing the relationship between the real estate sector and the environment. Among others it seems that four issues always come forward:

- Soil
- Air and atmosphere
- Materials and waste management
- Water.

Identifying these four impact categories and reviewing the literature, we can derive two possible scenarios for this study. Namely, Scenario A representing the real estate sector's impacts on the environment and Scenario B – the considerable impacts of the environmental factors on the maintenance and operation of a building.

Scenario A and B categories and preferences have been built on literature research and analysis, the author's perspective as a person with experience with GBCSs and in the same time as a student in environmental and resources management.

3.2.1 Scenario A - based on buildings' environmental impacts

As previously mentioned in chapter *Buildings 'Environmental Impacts* the real estate sector imposes some serious impacts on the environment and its resources that have captured the attention of scientists and practitioners. Based on that chapter *LEED's* and *BREEAM's* credits can be re-organized into new groups in order to comparably address the issues at hand. Five main groups of buildings' environmental impact categories have been identified:

- Energy Consumption/Performance - It is responsible for the depletion of resources (fossil fuels), significant share of green house gases (GHGs) released in the atmosphere, as well as the indoor conditions of our living or working places (e.g. for heating or cooling purposes).
- Materials – depletion of natural resources as one of the biggest impacts of the building sector on the environment
- Water – a resource necessary in the construction sector, for the extraction of materials. Still as a scarce resource the impacts of the RES on water should be minimized and water efficiency should be increased

- Soil – for example, soil compaction as a serious tread to the water infiltration and cleaning process, protection against flooding, etc.
- Waste –For example, the increasing consumption of goods and materials without proper sustainable management of the waste resulting after the end-of-life of products can continue the negative tendency of raw materials depletion and their unsecure supply.

New weighting will be given to the above five groups based on the attention they receive according to the reviewed literature and author's analysis, as well as their percentage contribution to the total utilization resources in Europe. Thus, for example, the energy consumption in buildings represents 40% of the total energy consumption in Europe (see Buildings 'Environmental Impacts). Together with the market's interest on this category, a higher weighting to this group of credits is to be expected. Nonetheless, after analyzing the reviewed literature, this scenario's weighting adjustment is developed from the perspective of the author of this study. The latter is further explained in *Chapter 1.3.6.2 Implementation of the methodology on Scenario A*, as why each category is more or less important than the others.

3.2.2 Scenario B - based on the environmental impacts on real estate sector

It is difficult, if not impossible, to point out which of the natural resources have a greater influence on the real estate sector or which is the most important for a development. Analogous to *Scenario A*, for the purpose of this scenario the literature analysis introduced in *Chapter 3.1.2 Environmental Impact on the Real Estate Sector* is used as a basis. The different environmental factors recognized in the literature reviewed can be divided into three major groups:

1. Natural resources – soil, water and materials
2. Exploitation of the natural resources – the energy sector
3. By-products from the natural resources and their relationship with the human activities – waste

The above suggests that the first three are the basic and most influential elements from an environmental point of view, as they supply the real estate sector with the necessary primary goods for developments. Thus, the buildings sector is strongly dependent on these natural resources through the limitation of their availability and regulations in place. In the same time, a strict distinction between their essential role and importance strongly depends on the point of view of the source or author presenting the information, i.e. geologist, hydrologist or research group more interested in the current raw materials situation.

On the other hand, the energy sector relies on the supply of all three, to produce the energy needed for the construction of a building and its daily operation. Even though in the developed world electricity is an integrated part of daily life and functioning, there are still a lot of places and regions where it is a luxury. Therefore, the unavailability of these natural resources, together with technical and engineering deficits, can put also limitation on the production of energy in different parts of the world and influence the real estate developments.

In terms of waste management, the real estate sector can minimize construction materials' and buildings' facility management costs, if a proper and integrated waste management are implemented. Thus, with a substitution of certain limited natural resources and materials with reused and recycled waste materials, the dependency of the sector on them can be decreased.

The presumptions in this chapter will be implemented in the pairwise comparison matrix for Scenario B.

3.2.3 Scenario C – based on expertise practical knowledge

The previous two scenarios have been based on the literature research that tries to comprehend the complex relation between the environment and the real estate sector and their impacts on one another. The reviewed literature is the result of years of experience and knowledge of authors with different background and expertise in the field. It is quite challenging to find an expert opinion that can address equally all the aspects of interactions between the two issues in question.

Nowadays the expectations of the employers to their employees are such that challenge the expertise of people only in one field. This is especially true when it comes to consultant companies. The qualifications of the consultants may vary but in the same time a basic understanding of all fields relevant to the tasks at hand, is required.

The following scenario is based on the expertise, previous knowledge, years of experience and different educational background of the consultants at *Alpha Energy&Environment Austria GmbH*. The company specializes, among others, in environmental consulting, especially in Green Building Certification Systems. Based on their experience with different projects, some conclusions of the importance of one category of credits in comparison to other have been made.

Two different scenarios are proposed – one that distinguishes between the different groups and another that places the different impact categories on the same level, in respect to their importance for a development's environmental performance.

The first one concentrates on the six credit categories, as defined for this study, and builds its preference value with the help of the combined method and tools described later, based on the following assumptions:

- *Site Selection* – This is considered to be the most influential one to the decision that a real estate developer has to make and the one that is most important to the certification of a building. Strongly depending on the location of a development, the negative footprint of a building can vary in decreasing or increasing manner. Whether one decides to build a new building or renovate already existing one, makes already a significant difference. In terms of a new property one may need to consider the need of developing new infrastructure, the utilization of materials with a low percentage of recycling content, implement a larger scope of mitigation measures to address the negative impacts of the construction process, etc. This imposes not only higher impacts on the environment and the physical surroundings, but also to the socio-economic aspects of the building, as well.

  One of the biggest advantages when renovating an existing building is the reuse/reutilization of land. As already the soil on-site has been compacted and a building stands in place, the utilization of this land for some other purpose is quite unlikely. Another important feature when focusing on existing buildings is the reuse and recycling of construction materials, resulting from the demolition or refurbishment processes during the construction period. Additionally, the needed infrastructure for the normal operation of the building, in most cases, has been already established.

- *Energy*– The experience shows that integrating sustainable practices in assets and focusing on the energy performance of a building, is the sphere with the greatest potential for savings (for examples, reduction CO_2 emissions, decreased energy consumption, etc.). Furthermore, from a technical point of view, the energy category is the one with the highest potential for the optimization of a building's daily-based operation.

- *Materials & Waste* – The practical experience shows that quite often these two categories are interrelated and no differentiation between their importance can be made. Diverting more construction waste from landfills, by recycling or reuse in construction processes, can reduce the utilization of raw materials and the negative impacts of their excavation. Nevertheless, there are already practices of recycling construction materials on site because of which further negative environmental impacts can be avoided.

- *Water* –Even though on a global scale water is one of the most important environmental factors that needs the attention and efforts of the specialists, so as to be preserved in a sustainable manner, here in Europe one can see it differently. Although, the water resources are also affected from the negative impacts of climate change that Europe faces, there is still no water scarcity that should be addressed. For example, Austria is a country with abundant water resources that are also well-utilized in the energy sector. Furthermore, the drinking water quality along with the good water infrastructure affects positively the balance of the water resources within the country. Consequently, as the consulting company in question and its projects are mainly situated within the boundaries of Austria, this credit category receives the lowest ranking within the systems.

Based on the consultants' experience, giving a straight forward ranking of the importance of the different impact categories in the GBCS is not an easy task. The environmental impact categories are closely connected to each other and very often depend on one another. As a result, there is a need for a scenario where all the categories receive the same importance and weighting is introduced. Thus, *Scenario C2* sets all credit groups on the same level and weights the different categories with the same factor of *16.67 %* (as by definition of this study - six categories that sum up to 100%). This contrasts with all other scenarios in the study, as in Scenario 0, for example, all the credit categories have individual category weighting. In the LEED system the category "Energy&Atmosphere" contributes with 37 credit points to the overall certification result while the "Water Efficiency" – only with 10 credit points. The same is also true for the BREEAM system: the credit category "Energy" with 19% and the "Water" category only with 6%.

This scenario is not going to be a subject of a further preference investigation and the method and tools implemented on the other scenarios will not be applied on Scenario C2. Instead the derived factor is implemented to each category and their respective elements.

3.3 Regrouping Credits and Credits' Categories

BREEAM and LEED are two systems that share a common idea, mitigation goals and impact categories. Still, the number of these categories, along with the individual credits, differs from each other. In order to compare the two systems in a comprehensive manner, the credits will be organized in new credit categories based on their objectives.

After analyzing the reviewed literature from different perspectives on the topic of RES and the environment and identifying the major impact categories and the scenarios, five major credit categories could be identified. Additional there is the need of introduction of a new compact category that can gather all credits that do have an important place in the systems but do not belong to none of the already proposed groups. All issues, i.e. credits, that do not characterize under one of the five identified categories are organized into a new credit category – Others.

For the purpose of this study the following credit categories have been distinguished:

- Site Selection,
- Energy & Atmosphere,
- Water Efficiency,
- Materials & Resources,
- Waste Management, and
- Others.

The first five categories incorporate the goals and objectives from the initial LEED and BREEAM systems mentioned in Chapter 2 Green Building Certification Systems (GBCSs). Still some of the credits originating from these categories have been relocated as to match an equivalent credit from the other system. For example, initially LEED's SSc8 Light Pollution Reduction credit has been included into LEED's "Site Selection" Category (Appendix 0, p. 116). After organizing the credits into new groups, the credit is part of the credit category "Others", sub-category "Pollution" (Appendix A, p. 140) as its corresponding credit from BREEAM Pol 4 Reduction of night time light pollution (Appendix A, p. 130). Similarly, the BREEAM credit Tra 3 Alternative modes of transport (Appendix 0, p. 108) is considered as part of the Site Selection category (Appendix B, 143) and thus matches the LEED credit SSc 4 Alternative Transport.

The credit category "Others" may not be seen straightforward as environmental force and incentive for driving the decision-makers in one direction or another, but they most certainly should not be neglected, as they can provide better management of the building, greater occupancy comfort and healthier environment for the tenants. In terms of Scenario C1, for example, this credit category receives much more interest from a consultant point of view as activities, such as living, sleeping, working and so on, take place indoor. It is essential that the indoor environment is designed to the highest standards to protect humans' health from the adverse impacts that a building can inflict to its occupants. The *Indoor Environmental Quality* is part of the category *"Other Credits"* with credits emphasizing on the air quality, thermal and visual comfort of the occupants (Appendix B, p. 156). Therefore, this group receives a higher ranking for Scenario C1 in comparison with the credit groups of *Materials, Waste and Water.*

Due to the reorganization of the different credits, not only the content of the categories has been brought at a more comparable level. Further attention is paid also to the number of elements in the different category groups. The table below gives an overview of the different categories and number of credits included in each certification system, respectively.

Table 4 Regrouping Credits – Overview

	BREEAM Number of Elements per Category	LEED Number of Elements per Category
Site Selection	9	13
Energy & Atmosphere	7	7
Water Efficiency	4	4
Materials & Resources	4	5
Waste Management	4	2
Others	17	20
Total	**45**	**51**

As it can be observed from Table 4, there is a slight difference between the number of elements in some of the credit categories, as well as the total number of credit elements in the two systems.

This step allows another comparison between BREEAM and LEED that once again aims at the possibility to set both systems to a more comparable level than the original ones.

Table 5 presents the credit points available for each category after regrouping the credits in the six new credit groups:

Table 5 Credit points BREEAM and LEED

	BREEAM Credit Points per Category	LEED Credit Points per Category
Site Selection	22	26
Energy & Atmosphere	27	35
Water Efficiency	9	10
Materials & Resources	11	11
Waste Management	6	2
Others	52	16
Total	**127**	**100**

The regrouping of the credits assists in the comparison of the two certification systems in general, even though there are differences between the individual categories. This is the result of the difference in number of elements in each category as well as in the credit points' assignment, as already described in *Chapter LEED*. For instance, all credits in BREEAM Certification gain credit points while the prerequisite credits in the LEED system do not contribute directly to the certification score and no credit points are assigned to them by fulfilling the credits' requirements.

Chapter 3.4 Normalization analyzes in detail the correlation of the credit points and their percentage share in the overall certification result.

Even though the intention of this paper is to drive the credits and their categories as close to one other as possible, there are still some small differences in the scope, the evaluating method for each credit, number of elements or credit points, that cannot be avoided. However, for the purpose of the current study these differences have been omitted.

3.4 Normalization

Before going into detailed description of the study's approach, one more issue should be closely considered – LEED and BREEAM distribute the weighting within the systems' categories and within the credits differently. For example, LEED has more transparent and comprehensive weighting approach assigning credit points (i.e. values) and their contribution to the overall certification score. Once a credit point has been earned, this adds one percent to the total result. Thus, it is easy to understand also from non-professional assessor (i.e. real estate developer) and sends a clear signal to all stakeholders – one credit point, one percent.

On the other hand, BREEAM allocates its weights and credit points rather differently within its system's categories. For instance, one credit point in the *Energy category* adds up only 0.70% to the total certification score. However, the same one credit value in the *Waste category* gains 1.25% for the overall certificate score. Of course, these proportions are dependent on the weighting boundaries of each category and the number of elements included. Nevertheless, understanding the gain of a credit point under this system might proof difficult to a non-professional, who is actually making the decision whether a certain issue deserves its team's attention, efforts and additional financing that it may demand.

In the overall result this difference between the two systems may not play a big role but considering comparison between two corresponding categories or individual credit elements might proof difficult.

In order to avoid further confusions and in the same time simplify the two systems, as well as their comparison, the differences must be minimized. This calls for a "process of reducing measurements to a "neutral" or "standard" scale" (ICRSNB, 2015). This process is called normalization.

For the aim of this study each section total credit points are defined to be identical to 100. In this manner the disparities between single elements within a category, i.e. credit points, in the two systems can be reduced. Thus, even though by default the *Site Selection category* in BREEAM system results in *22 credit points* and the one in LEED in *26 total points*, in the paper's scenarios they are equal and identical with the scale chosen (≡100). Applied to each category individually, by dividing the total section points by default with the total section points by definition and multiplying it with the individual credit points available to each credit, one can derive what is the meaning of one credit point in terms of credit score (in percentage) within the category for the developed *Scenarios A to C2*. Consequently, this gives the opportunity to compare elements and categories on more common basis as the points to each credit in the individual categories are more likely to add the same credit value (percentage) to the category score in LEED and BREEAM systems. This step is especially needed in the case of the BREEAM system to normalize the value of one credit point within the different credit categories.

The *Scenario 0* will not undergo any normalization as the purpose of this scenario in the study is to show the two certification systems with their original structure, categories, credits and credit points.

Table 6 presents the results of the normalization.

Table 6 Normalization Credit Points BREEAM and LEED

BREEAM/LEED Categories	Credit Points		Sc.0 (baseline/original) 1 point= % -credit score/value*		Sc.A 1 point= % -credit score/value		Sc.B 1 point= % -credit score/value		Sc.C1 1 point= % -credit score/value		Sc.C2 1 point= % -credit score/value	
	BREEAM	LEED	BREEAM	LEED	BREEAM	LEED	BREEAM	LEED	BREEAM	LEED	BREEAM	LEED
Energy	1	1	0.70	1	1.67	1.29	0.57	0.435	0.82	0.64	0.62	0.48
Water	1	1	0.67	1	0.83	0.75	2.61	2.35	0.28	0.25	1.85	1.67
Materials	1	1	1.14	1	2.35	2.35	2.14	2.14	0.62	0.62	1.52	1.52
Waste	1	1	1.25	1	0.72	2.15	1.18	3.55	1.13	3.4	2.78	8.34
Site Selection	1	1	0.82	1	0.65	0.55	1.07	0.90	2.22	1.88	0.76	0.64
Others	1	1	div.	1	0.06	0.19	0.14	0.44	0.25	0.8	0.32	1.04

* The corresponding weighting value for both LEED and BREEAM in percentage for 1 credit point. The credit score/value in percentage for the Scenario 0 (baseline scenario with the original categories, credits, weighting, etc.) and its contribution in the categories scores and the overall certification score without undergoing normalization.

As it could be anticipated, there are still differences between the systems and their credit points. As already mentioned in *Chapter Regrouping Credits and Credits' Categories,* due to variation in the number of elements and the credit points available in each category, these inequalities cannot be absolutely avoided.

Even though not entirely successful, this attempt to bring both systems closer to one another, links the categories in a pair wise manner and builds further the parallels between BREEAM and LEED.

An absolute comparison of the two GBCSs is not entirely possible, due to their structure, their content, the allocation of possible points for each credit and focus.

Keeping in mind the differences, the two systems and their weightings are the topic of consideration in the next few chapters.

Looking into details and shifting the weightings within the two systems and their categories, will assist answering the initial question of this study: *How to Choose the Most Suitable GBCS for your Project,* i.e. which system corresponds to the category of interest.

3.5 Pairwise comparison and scoring based on the AHP method

The dynamics and complexity of today's world make it impossible to solve a problem only by limiting our decisions to the context of its situation. The everyday decisions are results of the interactions of influencing factors from different spheres. Including all these factors into decision-making processes is not an easy task. The work of the decision-makers is additionally complicated as they are often too stressed out due to time limitations, overload with information and lack of knowledge in all relevant spheres that should be considered.

The purpose of this paper is to give an opportunity for the decision makers to choose the most suitable GBCS for their project by comparing the certification scores and the individual category scores for different scenarios developed for this study as well as the original certification systems. Numerous multi-criteria decision-making tools can be applied. The basic method used in the current paper is the pairwise comparison of different criterias, i.e. the credit categories, with the help of assigning scores to each comparison of two criterias and scoring the categories with the resulting preference values in terms of the different scenarios.

The pairwise comparison is well-known tool when it comes to multi-criteria decision-making. It has been developed through the years but the milestone was set in 1927 by the American psychometrician Louis Leon Thurstone when he introduced his Law of Comparative Judgments (Koczkodaj, 2015). The pairwise comparison received attention and was further developed to manage "the subjective and objective judgments about qualitative and/or quantitative criteria in multi-criteria decision making" (Gang Kou, 2016). This tool compares different indicators on one-to-one basis. Usually the decision makers or the team of experts have to do a "comparative judgements on the relative importance of each pair of indicators in terms of the criterion they measure" or represent (Mendoza, 1999). The goal of the comparative judgement is to allocate relative weights to the indicators which for this paper are the six identified credit categories. The judgments themselves are made with the support of different measurement scales developed by practitioners, such as: the geometric scale (Lootsman 1989), the logarithmic scale (Ishizaka et la. 2010) and the ratio scale (Saaty 1977). The last one is used in the Saaty AHP method and is the one that will be used in this study.

By using this scale and giving a score to the compared credit categories, one simplifies the judgements and the preferences of the decision-maker are more comprehensable (Xu, 2001). The comparative judgements and the resulting preference values are presented and calculated in the pairwise comparison matrix (PCM). The overall results of the matrix is the preference weighting values (scores) for each of the presented credit categories and their implementation on the developed scenarios.

However, when working with subjective or vague issues, the consistency of the pairwise comparison should be tested. In order to follow a straight line the consistency of the PCM will be evaluated with the consistency index (CI) also proposed by Saaty.

Due to the nature of the problem and the structure of the AHP method, some of the main steps and objectives of this method will be utilized for the pairwise comparison and the scoring of the credit categories.

The methodology of this study can be summarized in six basic steps :

1. Structuring the problem as a hierarchy
2. Pairwise comparison judgments
3. Pairwise comparison matrix (PCM)
4. Deriving the preference values for the scenarios
5. Evaluation of the consistency of the PCM
6. Applying the preference values, i.e. weights, to the scenarios and the credit categories

The next few paragraphs describe in detail the fundamentals behind these six steps which will be later on implemented to the study’s case scenarios.

The *first step* presents the hierarchical structure of the problem, including its goal, criteria and scenarios. The main goal of the implementation of the pairwise comparison and scoring tools in this paper is to assisst the real estate sector’s decision-makers in their choice of the most suitable Green Building Certification System for a project. As suggested in *Chapter 3.3 Regrouping Credits and Credits' Categories*, six criteria clusters, can be derived. The individual credits from the credit groups represent the sub-criteria that are exemplary represented in the implementation and the outcome chapters of the study. For detailed definition of this criteria and their respective sub-criteria, please review *Chapter 3.3* and the Annexes part at the end of the paper. The two major alternatives presented here are the LEED and BREEAM certification systems. However, their structures have been adopted for the four different scenarios which main aim is to challenge the initial hypothesis presented in the beginning of the study. As a result, there are two main alternatives for the two reference projects with four scenarios for the LEED system and four scenarios for the BREEAM system. The diagram below gives a simplified overview of the hierarchical structure of the problem at hand.

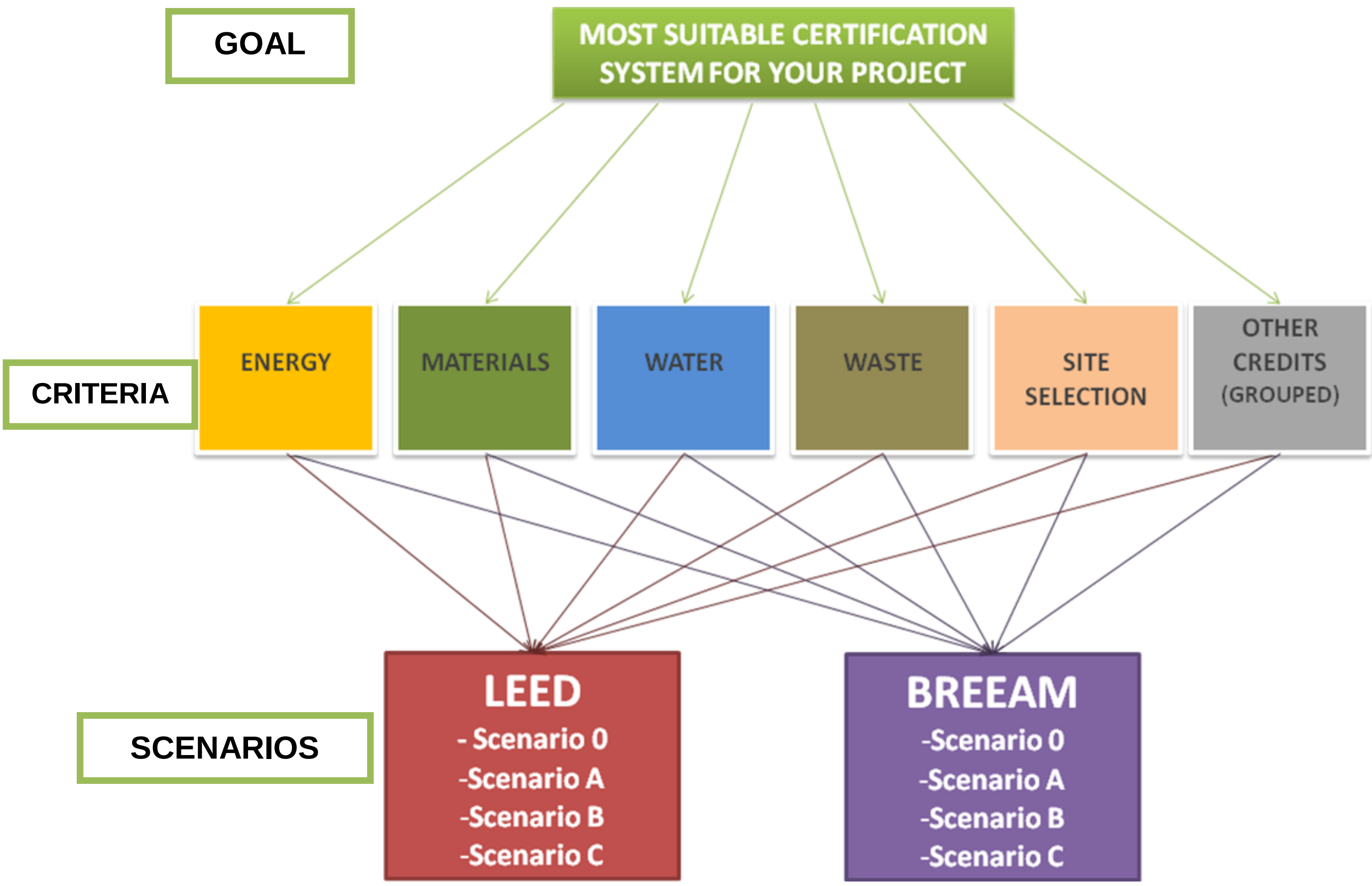


Figure 8 Structuring the problem as a hierarchy

The *second step* is the pairwise comparison and scoring applied on the different criteria, i.e. certification credit categories. As the author has already presented the information in *Chapter 3.1 The Real Estate Sector and the environment* each scenario is built on literature research, expert knowledge and the author's analysis. During the preparation of the pairwise comparison one should keep in mind that the comparison is not entirely objective, as it is influenced from the literature research and the author's expert knowledge and experience. Based on these conclusions the comparative judgments can be made in terms of the relative importance of one category to another. To translate these judgments into elements that can be compared more easily, integer numbers are assigned by the author of this study to the pairwise comparisons and thus each pair in question receives a score of importance, i.e. preference. There are many different scale types available but for this study the linear scale of Saaty is implemented. The scale, also known as the AHP absolute fundamental scale (Figueira, 2005), has a range between 1-9 and the meaning of the numbers assigned can be seen in the figure below:

Table 7 The AHP absolute fundamental scale (Saaty, 1990)

Option	*Numerical value(s)*
Equal	1
Marginally strong	3
Strong	5
Very strong	7
Extremely strong	9
Intermediate values to reflect fuzzy inputs	2,4,6,8
Reflecting dominance of second alternative compared with the first	Reciprocals

The methodology used in this study will not be applied on the baseline Scenario 0 as in this case the scenario preserves the initial and original structure and weightings within the LEED and BREEAM certification systems, in respect to the reference projects.

The *third step* takes further the pairwise comparison and sets a pairwise comparison matrix. In this case there is a six-by-six matrix where the diagonal equals 1. In the positions above the 1-diagonal elements, one inserts the score of each individual pairwise judgment comparison. In positions below this diagonal, one fills in the ratio scale of the different elements. This step, as well as all other steps, is implemented to each scenario individually (except Scenario 0).

Pairwise Comparison Matrix (PCM)

	Energy	Materials	Site Selection	Water	Waste	Others
Energy	1					
Materials		1				
Site Selection			1			
Water				1		
Waste					1	
Others						1
Sum						

The outcome of this matrix and the pairwise comparison is derived from the matrix equation below (Saaty, 1990):

$$\begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_n \end{array} \begin{array}{c} \begin{array}{cccc} A_1 & A_2 & \cdots & A_n \end{array} \\ \begin{pmatrix} w_1/w_1 & w_1/w_2 & \cdots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \cdots & w_2/w_n \\ \vdots & \vdots & & \vdots \\ w_n/w_1 & w_n/w_2 & \cdots & w_n/w_n \end{pmatrix} \end{array} \begin{pmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{pmatrix} \tag{1}$$

$$= n \begin{pmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{pmatrix}.$$

In order to derive the preference values (weights) required for the four scenarios, the “principal eigenvalue and the corresponding normalized right eigenvector” have been calculated (Bhushan, 2004).

Saaty has proposed a consistency index (CI) that is calculated with the help of the eigenvalue method, as shown in equation (2) (Ishizaka & Labib, 2009):

$$\mathrm{CI} = \frac{\lambda_{\max} - n}{n - 1}, \tag{2}$$

where $\lambda_{max} =$ maximal eigenvalue

The n in the equation represents the dimension of the matrix.

Taking the evaluation of the consistency of the matrix one step further, the consistency ratio (CR) calculation is the result of the ratio of CI and the random index (RI), i.e. (Ishizaka & Labib, 2009):

$$\mathbf{CR=CI/RI,} \qquad \mathbf{(3)}$$

where RI is obtained as an average CI of 500 randomly filled matrices and is summarized in the Saaty' table of random indices below (Ishizaka & Labib, 2009).

Table 8 Random indices from Saaty (1977)

n	3	4	5	6	7	8	9	10
RI	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

The random index used for the calculation of all consistency ratios throughout this study is marked in the Table 8.

Crucial for the consistency of the matrix is the value of the CR. As long as the consistency ratio is *below 10 %,* the matrix is "considered as having an acceptable consistency" (Ishizaka & Labib, 2009). Otherwise, one has to reconsider and review once more its pairwise judgment comparison.

The last *sixth step* is the implementation of the preference values obtained with the pairwise comparison and the scoring to each scenario and reference project. As previously mentioned the derived weights will be multiplied with the sub-criteria of each scenario and aggregated, to form the respective criterion total score in the system and scenario in question.

The pairwise comparison and the scoring tools' simplicity and mathematical nature allow the use of different softwares that can assist by the computation of the preference values from the pairwise comparison matrix along with the consistency ratio (CR). For this study MS Excel has been chosen.

The next chapter presents further detailed information on the scenarios build-up for this paper and the implementation of the described methodology each scenario separately.

3.6 Implementation of the Methodology to the Case Study Scenarios

The previous chapters gathered theoretical information, presented the main concepts and developed the methodology for this study, to put the results in practice in this chapter.

For each scenario a regrouping had to be done of its credits (sub-criteria) into the readjusted credit categories (criteria), normalization of its individual elements, as well as consideration for the presumed importance of the credit categories for the specific scenario. The implementation of the study's methodology will further readjust the weightings of each element and therefore their importance. Thus, the sensitivity of both Green Building Certification Systems (LEED and BREEAM) and their consistency will be evaluated.

3.6.1 Implementation Scenario 0

The goal of Scenario 0's is to present the performance of the chosen reference projects, regarding the original weights and categories' structure of the GBCSs, based on scientific findings, practitioners' experience and real estate developers' attitude toward sustainability within the limits of the construction sector.

Thus, the weights and preference values for this Scenario are not a subject of changes*. Appendix 0* represents the baseline of the BREEAM and LEED's available credit points, credit scores and total maximum certification score possible, as well as the preliminary check results for the two reference projects undertaken by the assessor.

3.6.2 Implementation of the methodology on Scenario A

The implementation of the methodology for the different scenarios is presented in the form of matrices, tables and computation of equations.

After establishing the hierarchical structure of the problem in *Chapter3.5 (*Figure 8*)*, the next steps are the pairwise comparison and scoring of the different criteria. The matrix below presents the result of the pairwise comparison in the context of Scenario A.

Table 9 The Pairwise Comparison Matrix - Scenario A

Pairwise Comparison Matrix - Scenario A

	Energy	Materials	Site Selection	Water	Waste	Others	x (i1) sum(1)	x (i1) sum(1)	x (i1) sum(1)	x (i1) sum(1)	x (i1) sum(1)	x (i1) sum(1)	Sum	Sum/6
Energy	**1**	3	5	7	7	9	0.518	0.623	0.514	0.420	0.298	0.333	2.706	**0.451**
Materials	0.33	**1**	3	5	7	7	0.173	0.208	0.308	0.300	0.298	0.259	1.546	**0.258**
Site Selection	0.20	0.33	**1**	3	5	5	0.104	0.069	0.103	0.180	0.213	0.185	0.853	**0.142**
Water	0.14	0.20	0.33	**1**	3	3	0.074	0.042	0.034	0.060	0.128	0.111	0.449	**0.075**
Waste	0.14	0.14	0.20	0.33	**1**	2	0.074	0.030	0.021	0.020	0.043	0.074	0.261	**0.043**
Others	0.11	0.14	0.20	0.33	0.5	**1**	0.058	0.030	0.021	0.020	0.021	0.037	0.186	**0.031**
Sum	1.93	4.82	9.73	16.67	23.5	27	1.000	1.000	1.000	1.000	1.000	1.000		**1.000**

Part I (Energy – Others columns)

Part II (x (i1) sum(1) columns)

Estimated Values (Sum)

Preference Values/ Preferences (Sum/6)

The first part of the matrix includes the comparative judgments based on the literature research conducted in *Chapter Buildings 'Environmental Impacts. Based* on the reviewed and analyzed literature in the chapter, the author made some subjective assumptions for the relative importance of each criterion (credit category) and took the role of an expert by conducting the comparative judgments statements. The different criteria are compared one by one and numbers are assigned according to judgment statements (see Table 7). The results of these assumptions are summarized in the pairwise comparison matrix (Table 9).

Let us have a closer look to the *Energy criteria* and its importance in comparison with the other criteria, in terms of Scenario A. For example, according to the findings from research, the *Energy criterion* is *"Marginally stronger"* than the *Materials criterion*. Therefore, one can assign the integer number of *3* in the matrix of comparative judgment. However, comparing the *Energy criteria* with the *Others criteria* (the grouped credits), one can assign the integer number *9 ("Extremely stronger"),* as the first criterion is strongly more preferred than the second one. Furthermore, the matrix includes also intermediate values to address comparison between criteria which are preferred more or less equally, but still a difference should be considered. This is for example the case between the categories *Waste and Others* pairwise comparison where the intermediate value of *2* is chosen.

The second part of *Table 9 The Pairwise Comparison Matrix - Scenario A* assists for the calculation of relative ratio and the computation of the estimated values for the table. It is the relation of the different criteria and the sum that they form in the first part of the matrix. These estimated values are the normalization of each column. The preferred values (i.e. preferences) can be derived from the normalized values (estimated values) and "the average of the corresponding entries in the columns" (Saaty T. L., 1999).

The outcomes of the pairwise comparison matrix introduce the preference values (weights) for Scenario A, for the different criteria, as follows:

- **Energy = 0.451**
- **Materials = 0.258**
- **Site selection = 0.142**

- **Water = 0.075**
- **Waste = 0.043**
- **Other credits = 0.031**

These values are applied to the criteria and sub-criteria of the two alternatives (*LEED and BREEAM*) by multiplying each sub-criteria with the corresponding preference value. The latter can be presented in the form of weighting factors (as they are obtained above). The total sum of the preference values is *1* or *100%,* depending on the variant chosen. In this paper the preference values are used as weighting factors, rather than percentage.

However, before applying the weighting factors to the scenario elements, one has to evaluate the consistency of the matrix. The method described in *Chapter 3.5* is used.

The *consistency ratio (CR)* uses the matrix and the resulting priority vector (preference values) to determine the reliability of the approach in three steps.

Step 1: Comparison matrix multiplied by the vector of properties (1)

The Matrix **Priority Vector** **Eigenvector of the Matrix**

$$\begin{pmatrix} 1 & 3 & 5 & 7 & 7 & 9 \\ 0.33 & 1 & 3 & 5 & 7 & 7 \\ 0.20 & 0.33 & 1 & 3 & 5 & 5 \\ 0.14 & 0.20 & 0.33 & 1 & 3 & 3 \\ 0.14 & 0.14 & 0.20 & 0.33 & 1 & 2 \\ 0.11 & 0.14 & 0.20 & 0.33 & 0.5 & 1 \end{pmatrix} \mathbf{x} \begin{pmatrix} 0.451 \\ 0.258 \\ 0.142 \\ 0.075 \\ 0.043 \\ 0.031 \end{pmatrix} = \begin{pmatrix} \mathbf{3.042} \\ \mathbf{1.730} \\ \mathbf{0.915} \\ \mathbf{0.462} \\ \mathbf{0.260} \\ \mathbf{0.193} \end{pmatrix}$$

The outcome of this multiplication is the eigenvector of the matrix which together with the priority vector form the maximum eigenvalue of the pairwise comparison matrix - $\boldsymbol{\Lambda_{max}}$(*step 2*). This step is followed by dividing the eigenvector of the matrix with the priority vector.

Step 2: Maximum eigenvalue of the judgment matrix - $\boldsymbol{\Lambda_{max}}$ (2)

$$\boldsymbol{\Lambda_{max}} = \begin{pmatrix} 6.75 & 6.72 & 6.43 & 6.17 & 5.98 & 6.22 \end{pmatrix} / 6 = \mathbf{6.379}$$

As proposed from Saaty (1977) the consistency index relates to the eigenvalue method (*step 3*) (Ishizaka & Labib, 2009).

According to *Chapter 3.5* and the definitions given for the consistency ratio (CR), the following information will be used as an input data for the CR calculation:

Step 3: Consistency Ratio (3)

N = 6 – dimensions of the matrix
RI = 1.24 - random index, increases with N
λ_{max}= 6.379 - dominating eigenvalue

$$\Rightarrow \textbf{CR = CI/RI => CR =} \left(\frac{\lambda_{max} - N}{N - 1} \middle/ RI \right)$$

$$= \left(\frac{6.379 - 6}{6 - 1} \right) / 1.24$$

$\Rightarrow$ **CR = 0.061 ≤ 10%**

As the value of the consistency ratio is less than 10 %, then the pairwise comparison matrix for Scenario A can be identified as consistent. Therefore, no further revision of the judgment pairwise comparisons is needed.

The final step of the methodology is the implementation (scoring) of the weighting factors (preference values) to the alternatives in Scenario A – the certification systems LEED and BREEAM. Each sub-criteria is multiplied with the respective weighting factor to get local rating for each criterion. The total aggregated sum of all local credit gives the overall rating achieved for every criterion (credit category's score). The results of the implementation of the pairwise comparison and scoring methods in this scenario are summarized in Appendix A and Appendix B, where the section scores for the BREEAM and LEED certifications for both reference projects are presented in detail.

To illustrate the integration of the new preference value in each criterion, closer look to the method implemented on a single credit is presented. For example, in the pre-check of Project A and its characteristics, the assessor has assigned 3 possible credit points (credit score 2.45%) (Appendix 0, p. 108) out of maximum 5 credit points for the *"Tra 1-Public Transport availability"* in BREEAM's *Site Selection* section. The equivalent credit in the LEED pre-assessment *("SSc4.1 Alternative Transport – Public Transport Access")* Project A scores 6 credit points (credit score 6%) (Appendix 0, p. 114) which is also the highest possible score for this credit.

Taking into consideration Scenario's A preference values, the *Site Selection section* contributes with *14.2%* to the final certification score for the project. Thus, the credits in this category, in both BREEAM and LEED certification systems, adopt the new weighting and achieve the following credit scores:

- *Tra 1 – Public Transport availability (Appendix A, p. 128):*
    - **3** credit points by assessor
    - 13.64 credit points by definition (after normalization, where 1 credit point ≡ 4.55)
    - Credit category weighting, resulting from Scenario A = 0.142

⇨ *13.64* **X** *0.142* = ***1.94*** % credit score

- *SSc4.1 Alternative Transport – Public Transport Access (Appendix A, p. 132):*
    - **6** credit points by assessor
    - 23.08 credit points by definition (after normalization, where 1 credit point ≡ 3.85)
    - Credit category weighting resulting from Scenario A = 0.142

⇨ *23.08* **X** *0.142* = **3.28 %** credit score

Even thought, the project does not change its location for the different systems, the certifications' requirements differ from one another, such that Project A can earn the maximum credit points under the LEED system, but only half of the available credits under BREEAM. This outcome suggests that although the preferences of the two systems for this category are identical, there are still other factors that greatly influence the final credit scores, i.e. fulfillment of the credit requirements.

The importance of the weighting system and whether it can be solely the foundation of the decisions taken from the real estate actors in a certification process is further investigated in the next chapters.

3.6.3 Implementation of the methodology on Scenario B

The implementation of the methodology for this scenario follows the steps already explained in the previous two chapters and similarly to Scenario A uses the assumptions made in *Chapter 3.1.2 Environmental Impact on the Real Estate Sector.* With further consideration, the following assumptions about the influence of these groups on buildings, e.g. within Green Building Certification Systems, can be made:

1. Soil = Water = Materials
2. Energy
3. Waste = Others

There are 6 main sub-criteria: Site Selection, Materials, Water, Energy, Waste and Others.

Table 10 The Pairwise Comparison Matrix - Scenario B

The Pairwise Comparison Matrix - Scenario B

	Site Selection	Materials	Water	Energy	Waste	Others	x (i1) sum(1)	x (i1) sum(1)	x (i1) sum(1)	x (i1) sum(1)	x (i1) sum(1)	x (i1) sum(1)	sum	Sum/6
Site Selection	**1**	1	1	2	3	3	0.240	0.240	0.240	0.261	0.214	0.214	1.409	**0.235**
Materials	1.00	**1**	1	2	3	3	0.240	0.240	0.240	0.261	0.214	0.214	1.409	**0.235**
Water	1.00	1.00	**1**	2	3	3	0.240	0.240	0.240	0.261	0.214	0.214	1.409	**0.235**
Energy	0.50	0.50	0.50	**1**	3	3	0.120	0.120	0.120	0.130	0.214	0.214	0.919	**0.153**
Waste	0.33	0.33	0.33	0.33	**1**	1	0.080	0.080	0.080	0.043	0.071	0.071	0.426	**0.071**
Others	0.33	0.33	0.33	0.33	1.00	**1**	0.080	0.080	0.080	0.043	0.071	0.071	0.426	**0.071**
Sum	4.17	4.17	4.17	7.67	14.00	14	1.000	1.000	1.000	1.000	1.000	1.000		**1.000**

Part I

Part II

Estimated Values

Preference Values/ Preferences

After completing the matrix, the following preference values for the different criteria are derived:

- **Site Selection = 0.235**
- **Materials = 0.235**
- **Water = 0.235**
- **Energy = 0.153**
- **Waste = 0.071**
- **Others = 0.071**

Their total sum is *1.000* which corresponds to *100%* in the GBCS.

As suggested in *Chapter 3.2.2 Scenario B - based on the environmental impacts on* , the first three groups dominate the others and thus receive around 70% share of the total system. The other 30% are divided between the “Energy” criteria (ca. 15%), “Waste” and “Others” (ca. 14%). They may not be seen straightforward as environmental force and incentive for driving the decision-makers in one direction or another, but they most certainly should not be neglected, as they can provide better management of the building, greater occupancy comfort and healthier environment for the tenants.

However, before applying the resulting preference values, i.e. scores to the two projects and the Green Building Certification Systems, the consistency ratio should be calculated, together with the reliability of the matrix. Thus, the matrix’s outputs are applied in the CR calculation below:

PC Matrix Consistency Ratio – Scenario B

Comparison matrix multiplied by the vector of properties (1)

$$\underbrace{\begin{pmatrix} 1 & 1 & 1 & 2 & 3 & 3 \\ 1.00 & 1 & 1 & 2 & 3 & 3 \\ 1.00 & 1.00 & 1 & 2 & 3 & 3 \\ 0.50 & 0.50 & 0.50 & 1 & 3 & 3 \\ 0.33 & 0.33 & 0.33 & 0.33 & 1 & 1 \\ 0.33 & 0.33 & 0.33 & 0.33 & 1.00 & 1 \end{pmatrix}}_{\textbf{The Matrix}} \times \underbrace{\begin{pmatrix} 0.235 \\ 0.235 \\ 0.235 \\ 0.153 \\ 0.071 \\ 0.071 \end{pmatrix}}_{\textbf{Priority Vector}} = \underbrace{\begin{pmatrix} \mathbf{2.584} \\ \mathbf{2.584} \\ \mathbf{2.584} \\ \mathbf{1.302} \\ \mathbf{0.237} \\ \mathbf{0.237} \end{pmatrix}}_{\textbf{Eigenvector of the Matrix}}$$

Maximum eigenvalue of the judgment matrix - λ_{max} (2)

$$\lambda_{max} = \begin{bmatrix} 11.00 & 11.00 & 11.00 & 8.50 & 3.33 & 3.33 \end{bmatrix} / 6 = \mathbf{8.028}$$

Following the methodology and analogue to the computations made for Scenario A, the calculated consistency ratio is:

- ⇨ **CR = 0.327≤ 10% => the matrix for Scenario B is consistent.**

Further, the resulting preferences will be implemented on the different credit groups as new, readjusted weighting factor. The implementation of the methods on both Project A and Project B, both for BREEAM and LEED certification systems, are presented in Appendix A and Appendix B in detail.

For instance, both systems consider the waste management during the construction phase of a project as an issue with significant impacts on the overall sustainable performance of a project. Therefore, the *Construction Waste Management* credit has been included in the certification process of BREEAM and LEED, respectively. The first gives a project the opportunity to gain a maximum of **3** credit points (or a credit score of *3.75%*) for the *"Wst 1 Construction Waste Management"* (Appendix 0, p. 111). The same project and the same issue, but under LEED, can earn at most 2 credit points (credit score 2%) for the *"MRc2 Construction Waste Management"* credit (Appendix 0, p. 120).

In the case of Scenario B's preference values and according to the preliminary assessment of Project B, for example, one can derive the following results:

- *Wst 1 – Construction Waste Management (*Appendix B*, p. 147):*
    - **2** credit points by assessor
    - 33.33 credit points by definition (after normalization, where 1 credit point ≡ 16.67)
    - Credit category weighting, resulting from Scenario B = 0.071

⇨ *33.33* **X** *0.071* = ***2.37*** %credit score

- *MRc2 Construction Waste Management (*Appendix B*, p. 155):*
    - **1** credit points by assessor (achievable)
    - 50.00 credit points by definition (after normalization, where 1 credit point ≡ 50.00)
    - Credit category weighting resulting from Scenario B = 0.071

⇨ *50.00* **X** *0.071* = **3.55** % credit score.

As it can be seen, Project B earns more points under the BREEAM system than under LEED. However, the project scores higher result with the LEED credit. Based only on the credit score for this issue, one may assume that the real estate decision-maker will choose the LEED system. However, one other factor should be kept in mind. There is a difference between the Waste category structures of both systems. On one hand, LEED has prerequisites that do not add additional value to the certification, but are mandatory in order the certification process to take place, i.e. no adjustment of the weighting of these category elements is possible. On the other hand, even though BREEAM's *Wst 1* is also a prerequisite to certain certification levels, it still contributes with credit points (credit score) to the final certification result.

Based on the above statement, one may suggest that the BREEAM system gives a better opportunity for achieving a higher certification level than LEED. From this point of view, the decision-maker may choose BREEAM, if he considers this assumption to be true.

It is not possible to give a straight forward answer under which system reference Project B will perform better in terms of certification. The overall performance of a project under the two certification systems depends not only on a single credit, but on the certification system as a whole.

Chapters 4 analyze in details the project's performance in each category, as well as the overall one – the certification level.

3.6.4 Implementation of the methodology on Scenario C

In the case of *Scenario C*, the practitioners have decided to derive two possible ranking scenarios: *Scenario C1* and *Scenario C2*.

The resulting preference values for *Scenario C1* is based on the practical experience of the consultants from *Alpha Energy & Environment Austria GmbH*. For a detailed description on the assumptions used for the pairwise comparison matrix, please see *Chapter 3.2.3 Scenario C – based on expertise practical knowledge.*

Summarizing the assumptions provided in the mentioned chapter, the credit categories for *Scenario C1* can be ranked as follows (starting with the most important to the least preferred category):

1. Site Selection
2. Energy
3. Other Credits
4. Materials = Waste
5. Water.

Analog to the other scenarios, once the initial assumptions have been laid down, the comparative judgment matrix can be derived (see *Table 11*).

The consistency of the matrix is questioned with the calculation of the consistency ratio, as shown in Equation(3), p. 65*.*

Table 11 The Pairwise comparison matrix - Scenario C1

Pairwise Comparison Matrix - Scenario C1

	Site Selection	Energy	Others	Waste	Materials	Water	x (i1) sum(1)	x (i1) sum(1)	x (i1) sum(1)	x (i1) sum(1)	x (i1) sum(1)	x (i1) sum(1)	sum	Sum/6
Site Selection	**1**	5	6	7	7	9	0.567	0.727	0.554	0.407	0.407	0.273	2.935	**0.489**
Energy	0.20	**1**	3	5	5	7	0.113	0.145	0.277	0.291	0.291	0.212	1.329	**0.222**
Others	0.17	0.33	**1**	3	3	6	0.095	0.048	0.092	0.174	0.174	0.182	0.766	**0.128**
Waste	0.14	0.20	0.33	**1**	1	5	0.081	0.029	0.031	0.058	0.058	0.152	0.409	**0.068**
Materials	0.14	0.20	0.33	1.00	**1**	5	0.081	0.029	0.031	0.058	0.058	0.152	0.409	**0.068**
Water	0.11	0.14	0.17	0.20	0.20	**1**	0.063	0.021	0.015	0.012	0.012	0.030	0.153	**0.025**
Sum	1.76	6.88	10.83	17.20	17.20	33	1.000	1.000	1.000	1.000	1.000	1.000		1.000

Part I

Part II

Estimated Values

Preference Values/ Preferences

Although the categories for this scenario are the same as in the first two, the outcomes of the basic assumptions of *Scenario C1* and the outcomes of the PC matrix above, generate a new set of weightings for our systems, as follows:

- **Site Selection = 0.489**
- **Energy = 0.222**
- **Others = 0.128**
- **Waste = 0.068**
- **Materials = 0.068**
- **Water = 0.025.**

Of course, the completeness of the systems still sums up 100%.

Once again, the consistency of the matrix is proven with the mathematical method below:

PC Matrix Consistency Ratio – Scenario C1

Comparison matrix multiplied by the vector of properties (1)

The Matrix **Priority Vector** **Eigenvector of the Matrix**

$$\begin{pmatrix} 1 & 3 & 5 & 6 & 7 & 9 \\ 0.20 & 1 & 3 & 5 & 5 & 7 \\ 0.17 & 0.33 & 1 & 3 & 3 & 6 \\ 0.14 & 0.20 & 0.33 & 1 & 1 & 5 \\ 0.14 & 0.20 & 0.33 & 1.00 & 1 & 5 \\ 0.11 & 0.14 & 0.17 & 0.20 & 0.20 & 1 \end{pmatrix} \mathbf{x} \begin{pmatrix} 0.489 \\ 0.222 \\ 0.128 \\ 0.068 \\ 0.068 \\ 0.025 \end{pmatrix} = \begin{pmatrix} \mathbf{3.545} \\ \mathbf{1.562} \\ \mathbf{0.844} \\ \mathbf{0.420} \\ \mathbf{0.420} \\ \mathbf{0.160} \end{pmatrix}$$

The maximum eigenvalue of the judgment matrix - λ_{max} (2)

$$\lambda_{max} = \begin{bmatrix} 7.25 & 7.05 & 6.61 & 6.17 & 6.17 & 6.28 \end{bmatrix} / 6 = \mathbf{6.589}$$

The derived consistency ration from the computation of Equation (3) is:

⇨ **CR = 0.095≤ 10% => the matrix for Scenario C1 is consistent.**

As the matrix for this scenario is consistent, the preference values derived from it will be applied on the categories and their sub-criteria, as to obtain the outcomes of the paper in the next chapters.

For a demonstration of the implementation of the above resulting preference values, again two credits are chosen. The first credits in the Energy category of BREEAM and LEED pay attention to the overall energy performance of the building. BREEAM system gives the opportunity to earn 15 points at most for the *"Ene 1 – Reduction of CO2 emissions"* (or credit score 10.56%) (Appendix 0, p. 107). At the same time, under LEED the *"EAc1 Optimize Energy Performance"* has 21 credit points available with a credit score of 21% (Appendix 0, p. 118). For instance, reference Project A achieves 10 and 17 credit points under BREEAM and LEED, respectively. Once the weighting resulting from PC matrix under Scenario C1 is applied to the project, the following results can be obtained:

- *Ene 1 – Reduction of CO2 emissions (*Appendix A*, p. 124):*
  - 10 credit points by assessor
  - 37.04 credit points by definition (after normalization, where 1 credit point ≡ 0.82)
  - Credit category weighting, resulting from Scenario A = 0.222

⇨ *37.04* **X** *0.222* = **8.22** % credit score

- *EAc1 Optimize Energy Performance (*Appendix A*, p. 135):*
  - **17** credit points by assessor
  - 48.57 credit points by definition (after normalization, where 1 credit point ≡ 0.63)
  - Credit category weighting resulting from Scenario A = 0.222

⇨ *48.57* **X** *0.222* = **10.78 %** credit score.

Even though, the two credits are managing the same issue, i.e. the energy performance of reference Project A, there is still a difference in the percentage score of the credits in the two systems. The implementation of the new preference values for Scenario C1 set the same weightings on the two credits Ene 1 (BREEAM) and EAc1 (LEED) but some disparities remain. The further investigation of these two examples is presented in the Chapter 5. Discussion **-** strengths and shortcoming.

Before going into the next chapter where the outcomes and conclusions of the study are presented, there is one more scenario that needs attention. As previously mentioned in *Chapter 3.2.3,* from practitioners' point of view, there is a need for a scenario where all categories within the GBCSs receive the same preference ranking and equals to one another, i.e. *Scenario C2*. Thus, the complicated and interrelated bonds between the categories can be analyzed from another perspective. Already in *Chapter 3.2.3, page 52* equal preferences have been assigned to the six categories. Therefore, in the case of *Scenario C2* not the individual credits are of interest for this study, but rather the section scores of each category and the final certification levels achieved. These two outcomes of the implementation of the pairwise comparison and the scoring methods in this scenario are subjects to *Chapter 4 Outcomes of the applied methodology.*

The next chapters present the results of the current study and seek for signals and conclusions that can assist the real estate developers and other interested parties, to choose the most suitable Green Building Certification System for their future projects.

4 Outcomes of the applied methodology

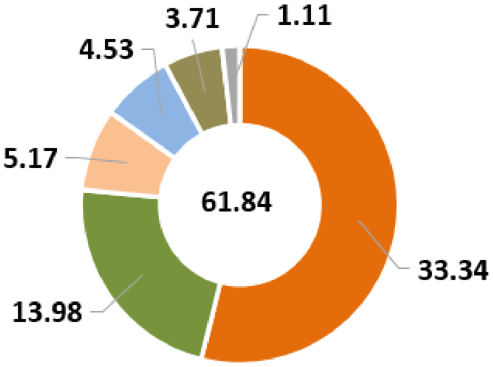
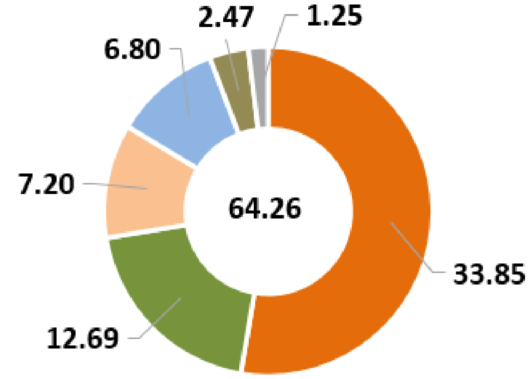
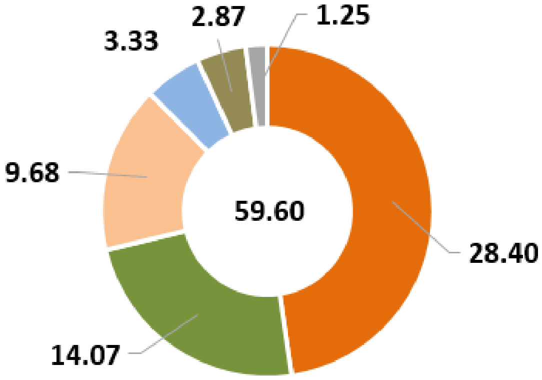
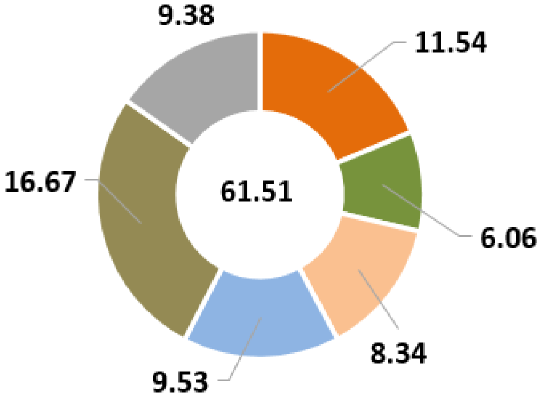
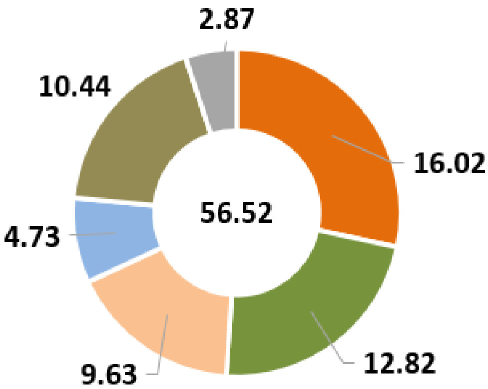
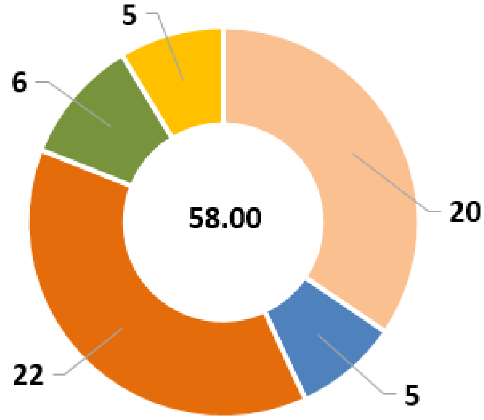
As it can be concluded from the implementation of the pairwise comparison and the scoring method on both reference projects and the given individual examples for each scenario, comparing and analyzing only single credits may not help a decision-maker, to choose the appropriate system for a project. This chapter further investigates the performance of both projects under the presented alternatives in this study.

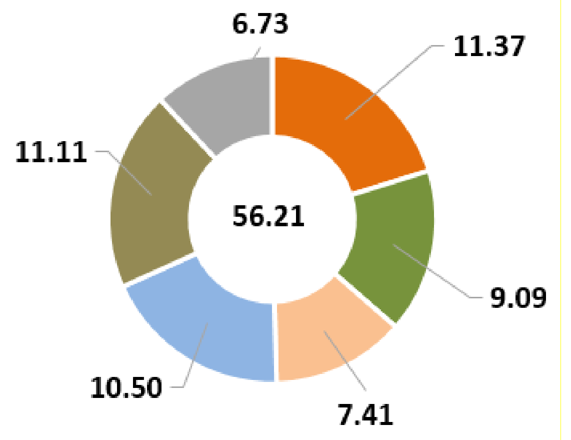
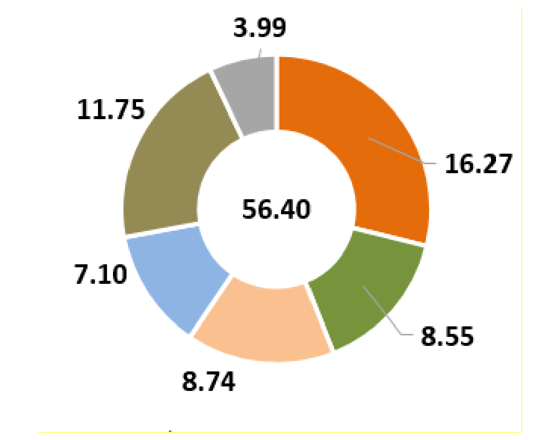
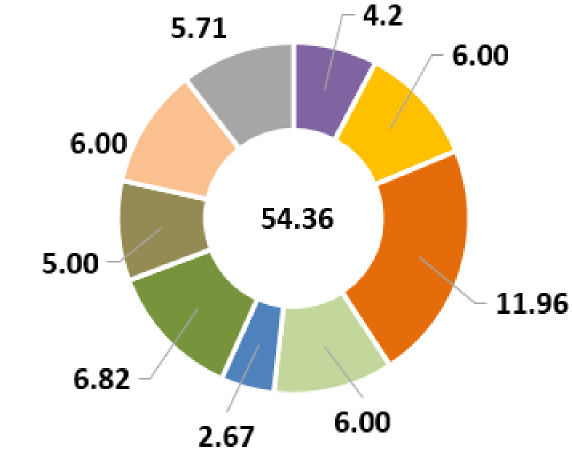
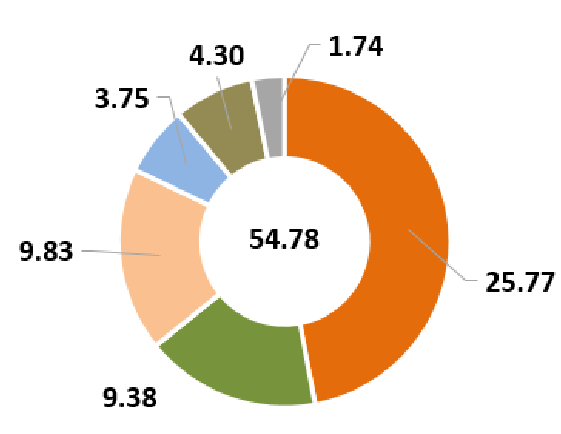
4.1 Certification Level

Once a preliminary certification check for a project has been fulfilled, the assessor pays attention at first to the overall certification level that a project can achieve. Thus, boundaries between possible, certain and achievable (but with additional inputs) can be differentiated. This is important in order to concentrate on the next step of a decision – which certificate level the real estate developer is willing to pursue.

This thesis attempts to bring BREEAM and LEED to a more comparable level. As it has been proven comparing the two systems might not be an easy task to perform but in the same time focusing only on certain aspects of the two systems may help to obtain some answers needed for the objectives of the study. The focus in this chapter is not on the certificate itself (“Very Good”, “Excellent”, “Silver” or “Gold”, for example), but rather on the final certification score (in percentage) of each project in each alternative. The table below presents a summary of the final results of the baseline scenario, as well for the other four scenarios for reference project A and reference project B, respectively.

Table 12 Summary Scenarios' Certification Scores [%]- BREEAM and LEED, Project A (Appendix A)

Ranking (highest to lowest)	**BREEAM Int. 2013 Certification Score [%]**	**Ranking** (highest to lowest**)**	**LEED 2009 C&S Certification Score [%]**
Scenario C1		**Scenario C1**	
Scenario A		**Scenario C2**	
Scenario B		**Scenario 0 (Baseline Scenario)**	

Ranking (highest to lowest)	**BREEAM Int. 2013 Certification Score [%]**	**Ranking** (highest to lowest)	**LEED 2009 C&S Certification Score [%]**
Scenario C2		**Scenario B**	
Scenario 0 (Baseline Scenario)		**Scenario A**	

Legend BREEAM Scenario 0

- Management
- Health & Wellbeng
- Energy
- Transport
- Water
- Materials
- Waste
- Land Use & Ecology
- Pollution

Legend LEED Scenario 0

- Sustainable Sites
- Water Efficiency
- Energy & Atmosphere
- Materials & Resources
- Indoor Environmental Quality

Legend Scenarios A – C2

- Energy
- Materials
- Site Selection
- Water
- Waste
- Other Credits

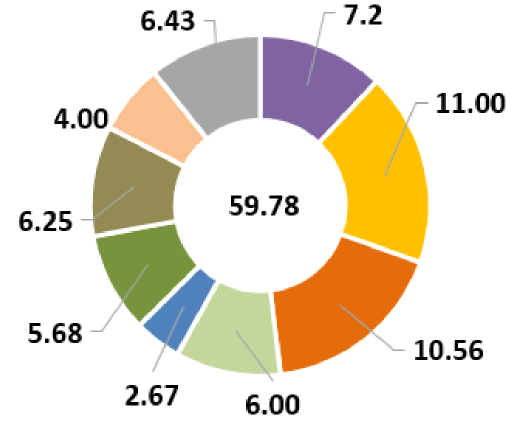
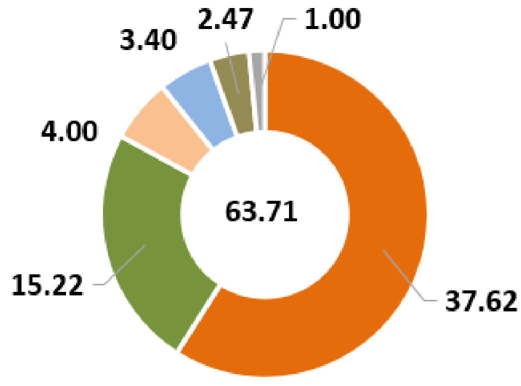
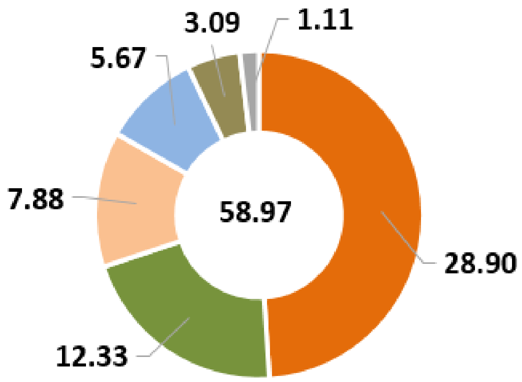
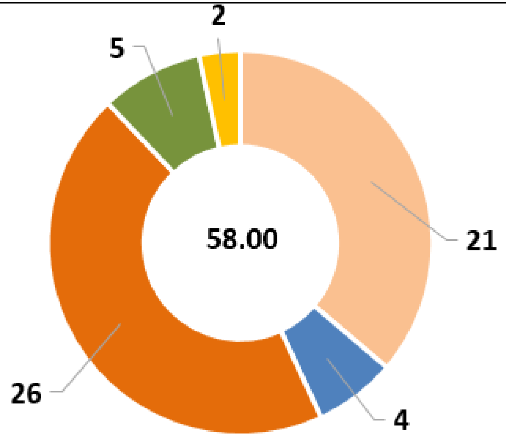
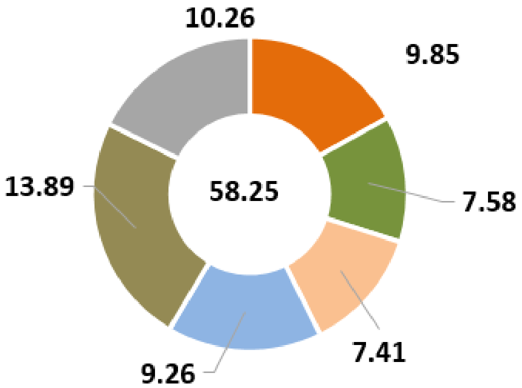
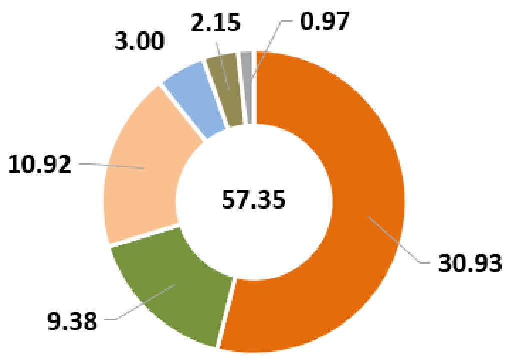
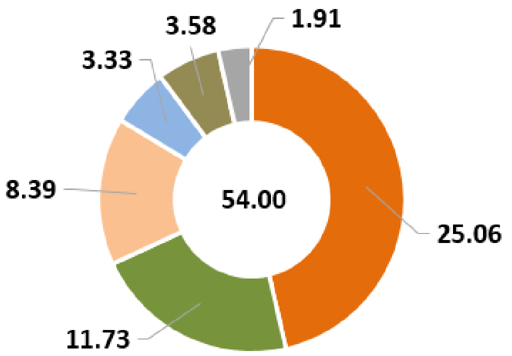
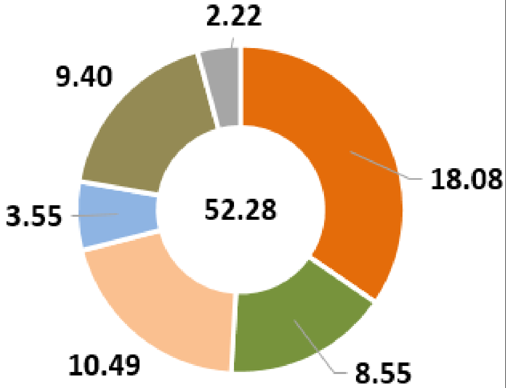
Some interesting conclusions for the performance of Project A under both GBCSs can be derived from *Table 12*.

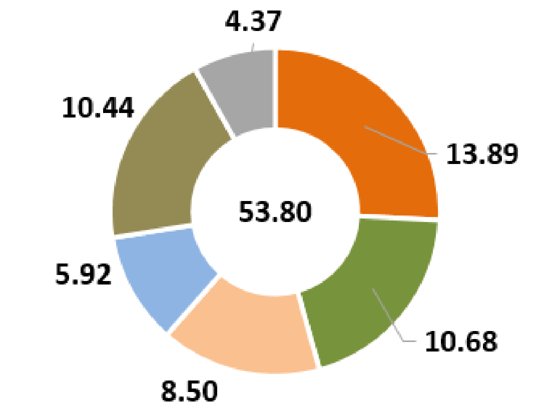
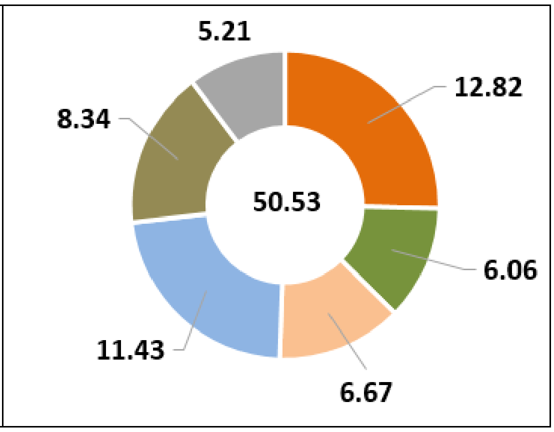
At first glance, all the certification scores lay in a range between *54%* and *64%*. However, three out of five scenarios (including the baseline scenario) Project A performs better, or can achieve a better certification score and label, under the LEED certification system – *Scenarios 0, C1 and C2*. In this case, LEED slightly prevails over BREEAM for this reference project.

In the same time, the highest possible certification score, with *64.26%,* the project achieves in *Scenario C1* under the LEED certification. On the other hand, the lowest score, with *54.36%,* estimated with this study methodology is part of the BREEAM certification and the preliminary assessment of the project – *Scenario 0*. This further leans Project A towards LEED certification system, as the more appropriate one between the two GBCSs in question.

To investigate this tendency and analyze it further, Project B's certification scores are also compared in a similar manner in *Table 13.*

Table 13 Summary Scenarios' Certification Scores [%]- BREEAM and LEED, Project B (Appendix B)

Ranking (highest to lowest)	**BREEAM Int. 2013 Certification Score [%]**	**Ranking** (highest to lowest)	**LEED 2009 C&S Certification Score [%]**
Scenario 0 (Baseline Scenario)		**Scenario C1**	
Scenario C1		**Scenario 0** (Baseline Scenario)	
Scenario C2		**Scenario A**	
Scenario A		**Scenario B**	

Scenario B		**Scenario C2**	

<u>Legend BREEAM Scenario 0</u>

- Management
- Health & Wellbeng
- Energy
- Transport
- Water
- Materials
- Waste
- Land Use & Ecology
- Pollution

<u>Legend LEED Scenario</u>

- Sustainable Sites
- Water Efficiency
- Energy & Atmosphere
- Materials & Resources
- Indoor Environmental Quality

<u>Legend Scenarios A – C2</u>

- Energy
- Materials
- Site Selection
- Water
- Waste
- Other Credits

Similar to the results of Project A, Project B's certification scores lay in range between *50%* and *64%*. However, in the case of Project B in three out the five scenarios the project can gain a better certification score with BREEAM certification. These are *Scenarios 0, B and C2*. Therefore, there is a slight advantage for the BREEAM system for this reference project.

Nevertheless, Project B can achieve its highest certification score *(63.71%)* also with Scenario C1, under the LEED system. According to this assumption this project should tend toward LEED. However, the lowest certification score that Project B may achieve is as well under the LEED certification and *Scenario C2* (50.53%). Therefore, comparing only these two factors is not sufficient to clearly recognize whether LEED is the most appropriate system for the project in question.

As these two assumptions do not give a conclusive answer which of the two systems is more appropriate for Project B, further detailed analyze is needed, to provide a clear message to the decision-makers.

The outcomes from this chapter can be summarized in three main points:

1. Three out of five scenarios (including the Baseline Scenario) Project A leans toward the LEED certification system, while Project B – towards BREEAM certification system.
2. Both reference projects can gain their best certification score with Scenario C1 (the practitioners' scenario) under LEED.
3. Both projects certification scores lay in a range around *10-14%* between their highest and lowest estimated certification overall result.

The next chapter seeks further for clear signals whether a single system can be assigned to each project by comparing the six categories of the systems and their outcomes in the different scenarios.

4.2 Categories scores

As the previous chapter suggested, the practitioners' recommendation and the decision which certification system is the most suitable for one's project, should not be solely based on the final certification score. A comparison between the individual category groups of both systems, could give further insight about the performance of a project under a particular GBCS. The outcomes of this chapter are based on the summaries of the credit category scores presented in the Appendix sections of this paper.

Once the individual categories have been compared for all scenarios in terms of a particular project, an interesting fact captures one's attention. There are two categories that are not influenced from a project or the different scenarios, and always perform in favor of one of the two certification system – the categories *"Materials" and "Site Selection".* The first always tend to prevail towards BREEAM over the LEED credit score for both projects. Thus, one can assume that the BREEAM system gives a better possibility to the development's team to earn credit points under the requirements of the *BREEAM's Materials criteria*. This may influence the final choice of a certification system of the decision-maker, if a high importance is put on this issue and the development's main focus should be laid upon this single criterion. On the contrary, the second category*; "Site Selection",* incline toward LEED certification system, no matter the project or scenario. Consequently, if the credits in this category meet the objectives of the decision-making team, it could be decided to undergo LEED certification and emphasize the topics covered in the *"Site Selection"* category.

The same cannot be observed in the other four categories. As the results in the Appendix section suggest, the *"Energy", "Water", "Waste" and "Other credits"* categories strongly depend on the projects themselves. For example, if Project A performs better under the BREEAM "*Energy*" category, Project B, for instance, performs better under LEED *"Energy"* category's requirements.

Other differences between the two projects' performances under the alternative scenarios, can be also identified. Namely, comparing one category and one project in all the scenarios, can help to identify, under which of the two systems a project performs, in terms of section credit score, better. The Table 14 summarizes these comparisons for each reference project.

Table 14 Scenarios Categories Comparison - Project A & Project B

Category	Project A		Project B	
	Scenario 0	Scenarios A – C2	Scenario 0	Scenarios A – C2
Energy	LEED	-3xBREEAM -1xLEED	LEED	-3xLEED -1xBREEAM
Materials	BREEAM	4xBREEAM	BREEAM	**4xBREEAM**
Site Selection	LEED	**4xLEED**	LEED	4xLEED
Water	LEED	**-3xLEED** -1xBREEAM	LEED	**-3xBREEAM** -1xLEED
Waste	BREEAM	**4xLEED**	BREEAM	**4xBREEAM**
Others	BREEAM	**4xLEED**	BREEAM	**4xBREEAM**
Overall Tendency	3xLEED, 3xBREEAM	**4x LEED,** 2xBREEAM	3xLEED, 3xBREEAM	**4xBREEAM**, 2xLEED

More details can be found in the Appendix Section

As it can be observed, Project A always perform better under the LEED certification system, in terms of the *"Waste" and "Other credits" categories*. On the other hand, for Project B, these two categories always tend to be more favorable for the project under the BREEAM certification system.

An individual assumption for each category and its contribution to the certification result of a project can be also made based on the table. For example, Project A performs better according to the LEED *"Water" category* in three out of four scenarios. Thus, an assumption that this project will achieve always a better performance (section score) under this system, can be made. The same is also true in the case of Project B. For instance, the same *"Water"* category achieves better results in three out four alternatives under BREEAM. Therefore, this particular project will perform in terms of water objectives always better under the BREEAM system requirements.

In comparison to the overall tendency of *Scenario 0* for both projects where there is no obvious favorite system for either of the projects (based on the categories), the alternatives generate no clear answer which system is more suitable for each project, respectively. *Project A* has tendency to the *LEED* system – with four out of six categories favoring this certification process. Interesting fact is that the certification pre-assessment overall result (Scenario 0) also tends toward LEED (based only on the certification's score in percent) rather than BREEAM.

Similarly, *Project B* also tends to favor one of the two systems – *BREEAM*. Exactly in the same manner, the methodology of this study identifies that four out of the six categories have better performance chance under BREEAM. *Project B* gains a better certification score (in percentage) with BREEAM than LEED.

Even though, there are uncertainties regarding the implementation of the study and some omitted factors, it seems that the methodology developed can assist practitioners and real estate decision-makers to choose the most suitable certification system for a project.

5 Discussion - strengths and shortcoming

Certain methods and tools have been used while developing this thesis, attempting to reduce the differences between the BREEAM and LEED certification system, presenting the complex relationship of the real estate sector and the environment, and in the same time preserving an objectivity of the author. These issues can be seen as strengths and shortcomings. Some examples are given in this chapter and the author of the paper attempts to review them with more critical approach.

One of the main advantages of the study is its various perspectives. The first two scenarios (A and B) are based on the literature review of different experts from different fields and focus. Looking at the relationship of the real estate sector and the environment from two perspectives gives one the opportunity to investigate the correlation of the two and to understand some of the actions that real estate developers or scientists and scholars are taking into consideration. The author of the study suggests that only by understanding this relationship and the interest invested in it, one can make a sound decision whether to build a development and is there an opportunity to optimize it through a Green Building Certification, for example. The analyze and the base of Scenario A and Scenario B have been performed from the paper's author. This sets the question to what extend are the two scenarios objective. The same question can be asked for Scenario C that have been developed entirely on the expert level from assessor in Germany and Austria and their experience with certification systems. Of course, there is no guarantee that an absolute objectivity has been fulfilled but the author attempted to summarize only the opinion of scientists, real estate developers, practitioners and other related actors involved. On the other hand, as one is seeking for related information to the GBCSs BREEAM and LEED and their credits and categories, one is looking mostly only in the direction where there is a common ground between environment, developments, and Green Building Certification Systems, omitting for example the influence of politics and other law-making circles.

Both BREEAM and LEED are developed on national level at first. They have been concentrated on regulations and issues at local level rather than on global one. Therefore, there is no surprise that that are still disparities not only in the requirements and the scope of the two systems, but also in their weighting methods. Scenario 0 (the baseline scenario) has presented both systems in their original structure. This step is important for the preliminary assessment of the two reference projects and the initial systems, but not very convenient when it comes to comparison of the two systems. Due to the differences of the BREEAM and LEED presented in this study, Scenario 0 gives one the opportunity to compare only the final certification score of each reference project without the possibility to break the systems into more detailed comparison, i.e. credits and category basis.

One further step of the methodology of the paper helps in the comparison of the other scenarios (A-C2) – the regrouping of the credits in new credit categories while preserving the initial scope and content of the initial certification systems. Thus, the two systems are brought closer together and a detailed analysis of the differences or similarities in both systems can be performed. The results of the comparison of two corresponding credit categories can assist a real estate developer in which direction or which system should be applied upon a development.

The difficulties of comparing and analyzing the two systems comes across the different credits and the meaning of a single allocated credit point. As mentioned before, the LEED system simply suggests that one gained credit point contributes with one percent to the overall category and certification score. However, in the BREEAM system this is not as simple. There each credit point can contribute with different percentage depending on the individual credit categories. Therefore, the study conducted a normalization of each credit category after the regrouping of the credits into the new structure for Scenarios A-C2. After the normalization there are still differences in the corresponding credits from both system. This is due to the different number of elements in the credit categories as there are no credits that have been omitted from the study and in the same time there are not always corresponding credits. Thus, the normalization of the credit importance in the two systems is not entirely identical but the difference between each point is as a minimum reduced.

The methods and tools applied in the study are rather simple and vastly used when it comes to multi-criteria decision-making problems. The pairwise comparison and scoring and their implementation in an Excel-tool can be easily utilized even from a non-professional. Thus, developed as a tool the methodology of the thesis can assist in the decision-making process the different actors when it comes to choosing between

BREEAM and LEED certification system. The Analytic Hierarchy Process, used in the current study with some of its scales and structure, cannot be entirely implemented. The goal of the study is not to develop a total new system, in terms of weighting, scope, etc. and therefore there is no need of identifying a best or worst scenario. The objective of the paper is the comparison of two certification system and giving an answer, which one is better for each of the reference projects individually. The four different scenarios give the opportunity for finding out how each system and the reference projects are reacting to a shift in the weighting system and the structure of the GBCSs, and does this result in a pattern. In Chapter 4 some correlation between the systems and the reference projects has been reviewed and conclusions could be made.

Taking into consideration the implementation of the methods and tools one can have a closer look to the examples given. In Scenario A, for example (Chapter 3.6.2,p. 73), the implementation on two credits is presented, related with the public transport availability near the development (Project A). The analysis of these two credits shows that choosing for this instance which system is better for one's project depends strongly on the motivation of the decision-maker. If he considers only the final certification score as an important factor for his decisions, he will prefer the one credit, respectively system, which adds up more value to the final certification level, i.e. LEED. On the other hand, if he wants to base his decision upon the requirements of the credits and he assumes that BREEAM requirements' meet in a better manner his willingness to integrate sustainability practice in the development, he may also choose the BREEAM system.

If we consider the two credit examples given for Scenario C1 (Chapter 3.6.4, p. 83). and their score there are not easy to compare. First, the two systems differ in the initial number of credit points available. Therefore, the extent to which this project fulfills the requirements of these credits under both systems, may assist the decision-maker for the better understanding under which system the project will perform better in term of energy efficiency. Taking a closer look to the maximum available credit points of each credit and the achieved ones, we can conclude the following:

- Under BREEAM certification system Project A fulfills around 66% (10 credit points) of the total credit requirements
- Under LEED – Project A fulfills about 80% of the total credit requirements.

Taking into consideration the second statement, the reference project's energy performance under LEED is with about *14%* better than under BREEAM. However, this is not exactly possible as the project in question has the same characteristics, no matter under which system it is certified.

On the other hand, if we consider the initial maximum credit points once more, LEED has from the beginning with *16%* more credit points than BREEAM. This said, and keeping in mind the difference in the credit performance (see above), the 10 BREEAM credit points for this issue and the 17 LEED credit points are at the same level.

What makes the difference in this case? Again, the content of each credit with its requirements, the assessment method of the energy performance of the building and the necessary evidences for achieving the credit points, make this difference. Nevertheless, the subjective opinion of the decision-maker and its preference for an assessment method will play an influential role when choosing between these two criteria.

These are just a few examples of the shortcomings and advantages of comparison of the two systems – BREEAM and LEED. Keeping them in mind, some conclusions and recommendations from this study can be gathered in the next chapter.

6 Main conclusions of the Study

The objective of this paper is to identify the most appropriate Green Building Certification System for two reference projects developed in the city of Vienna, Austria. Both projects have been chosen to be similar in their characteristics, in terms of building use, location, area and other factors specified in *Chapter2.3.* Based on a literature research and practitioners experience in this sphere, different alternative scenarios for the evaluation of the performance of the projects according to GBCS have been developed.

As *Chapter 4. Outcomes of the applied methodology* suggests, there are two main factors that can assist to identify the most suitable system for each project. The outcomes in the certification score for each project in every scenario is an important step. One can make an assumption that the higher the certification score of a project in one system is, the more requirements have been fulfilled and more sustainable issues have been addressed within the planning and construction phase of a development. Thus, *Project A* can be defined as more sustainable or more satisfactory for its developer and users, when it undergoes certification under the LEED system. This also corresponds to the initial result from the pre-assessment of the project. Furthermore, in reality the project has been actually certified with *LEED Core&Shell Pre-certificate in Gold*. The same conclusion can be derived also for *Project B* after the analysis in this study. However, this project can achieve a better certification score and implement more sustainable features with the BREEAM certification system. In addition to this conclusion, the project scores a better certification score also in the Baseline Scenario and it is actually certified with *BREEAM Certificate "Good".*

In order to be certain, whether there is really a link between a project and a certification system, one should consider the performance of the project for each credit category, individually. As it turns out there are categories that are not influenced from the alternatives and in most cases a particular project tends always to achieve a better section score under one or the other system. The summarized results of *Chapter 4.2* support once more the conclusions from *Chapter4.1,* by identifying LEED for Project A and BREEAM for Project B, as the most suitable systems for these projects.

However, one should keep in mind that these results are true for this study, but there are also other factors that play an important role in real time decision-making, such as:

- Certification process (certification duration)
- Additional certification related costs – during planning, fulfilling the system's requirements, materials, etc.
- Type and amount of documentation needed
- Certification fees
- Goals of the real estate developer and their level of commitment to sustainable practices
- Whether the real estate developer is an owner and occupant at the same time, or wants to sell the development after construction, or rent it, etc.

There are many other factors that can influence the choice of a certification system from economical, environmental and social perspective. But there is also a very subjective aspect when it comes to choosing a Green Building Certification System – the preference of a real estate developer to one of the systems. Many decision-makers in this field that have an international portfolio might prefer LEED certificates, as it is well recognized worldwide. For a developer whose main focus is here in Europe, BREEAM, or other European certification systems, might seem more attractive.

Nevertheless, the study develops a step by step methodology that can assist practitioners and other real estate sector stakeholders, how to choose the most appropriate Green Building Certification System for their projects.

6.1 Review of the Initial Hypothesis

So far the pairwise comparison methodology applied upon the GBCSs and the reference projects proofs to serve its purpose. However, still remains the question whether the study justifies its initial hypothesis.

In the Introduction Chapter two main assumptions have been made:

- Achieving higher certification in one system, in comparison to the other, does not automatically suggest that the system will perform better in all its categories and will therefore achieve higher savings in sphere such as energy consumption, water consumption or resource efficiency.

- The above also implies when one considers the investment returns, occupants comfort and satisfaction.

The first hypothesis has proven to be correct. As it has been seen, achieving a higher certification score in one system does imply that most of the categories perform better under the certification system in question, but does not automatically suggests that all categories do so. In the cases of both projects, two or more categories tended to the other system, opposite to the final system choice.

Similarly, the second part of the hypothesis is not universally true for all projects and in every case. Even if a project achieves a higher certificate, in terms of final certification score and label, this may be the result of high performance in four out of six categories, where the other two have been poorly addressed.

In conclusion, readjusting the weightings of each category in different scenarios, made it possible to analyze the sensitivity of LEED and BREEAM and illustrate the relation between the level of certification and its credit categories.

6.2 Recommendations for Future Research Topics

As it turns out the methodology used in this study corresponds to the pre-check overall certification results under which each of the two projects perform better and in the same time to the chosen certification system in reality. This sensitivity check of the weightings of the two systems can be further developed into a more universal model, with less uncertainties, that could assist assessors and decision-makers in their conclusion to which certification system should be applied on a project, instead of basing their recommendation only on the certification's overall result.

Also, beneficial to the right choice of a system is the comparison of two or more certification systems. This analyzes the performance of a project under different requirements and perspectives, and increases the level of reliability for a chosen certification system.

Further investigation of the individual criteria and their actual performance can also assist the choice by considering different criteria outcomes, such as:

- The actual Energy savings/Water savings/Materials reduction accomplished through project's certification in one or another GBCS;
- Life cycle assessment of the impact of the building;
- The better integration of the national standards and norms in the GBCS corresponding to the location of the development.

Nevertheless, implementing the national strategies and standards in the GBCSs may be the right motivation for the real estate stakeholders to turn more often to sustainability certification of their projects, or in general to sustainability practices in their day–to-day business.

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Appendix 0

Table 15 BREEAM International 2013 – Scenario 0

Management							
		Max. Credit Points	Max. Credit Score [%]	Credit Points Achieved Project A	Credit Score Achieved Project A [%]	Credit Points Achieved Project B	Credit Score Achieved Project B [%]
Management	Man 1 - Sustainable Procurement	9	4.70	4	2.4	4	2.4
	Man 2 - Responsible construction practices	2	1.04	1	0.6	1	0.6
	Man 3 - Construction Site Impacts	5	2.61	1	0.6	2	1.2
	Man 4 - Stakeholder participation	4	2.09	1	0.6	2	1.2
	Man 5 - Life Cycle cost and service life planning	3	1.57	0	0	3	1.8
Section Total		23	12	7	4.2	12	7.2

Health & Wellbeing							
		Max. Credit Points	Max. Credit Score [%]	Credit Points Achieved Project A	Credit Score Achieved Project A [%]	Credit Points Achieved Project B	Credit Score Achieved Project B [%]
Health & Wellbeing	Hea 1 - Visual Comfort	4	4	1	1	2	2
	Hea 2 - Indoor air quality	4	4	2	2	3	3
	Hea 3 - Thermal comfort	2	2	2	2	2	2
	Hea 4 - Water quality	1	1	0	0	1	1
	Hea 5 - Acoustic performance	2	2	1	1	2	2
	Hea 6 - Safe access	1	1	0	0	1	1
	Hea 7 - Hazards	1	1	0	0	0	0
Section Total		15	15	6	6.00	11	11.00

Energy							
		Max. Credit Points	Max. Credit Score [%]	Credit Points Achieved Project A	Credit Score Achieved Project A [%]	Credit Points Achieved Project B	Credit Score Achieved Project B [%]
Energy	Ene 1 - Reduction of CO2 emissions	15	10.56	10	7.04	5	3.52
	Ene 2 - Energy monitoring	2	1.41	2	1.41	2	1.41
	Ene 3 - External Lighting	1	0.70	1	0.70	1	0.70
	Ene 4 - Low and zero carbon technologies	2	1.41	1	0.70	4	2.81
	Ene 5 - Energy efficient cold storage	3	2.11	2	1.41	1	0.70
	Ene 6 - Energy efficient tranportation systems	2	1.41	1	0.70	1	0.70
	Ene 8 - Energy efficient equipment	2	1.41	0	0.00	1	0.70
Section Total		27	19.00	17	11.96	15	10.56

Transport							
		Max. Credit Points	Max. Credit Score [%]	Credit Points Achieved Project A	Credit Score Achieved Project A [%]	Credit Points Achieved Project B	Credit Score Achieved Project B [%]
Transport	Tra 1 - Public transport accessibility	5	3.33	3	2.00	3	2.00
	Tra 2 - Proximity to amenities	2	1.33	2	1.33	2	1.33
	Tra 3 - Alternative modes of transport	2	1.33	2	1.33	2	1.33
	Tra 4 - Maximum car parking capacity	2	1.33	2	1.33	1	0.67
	Tra 5 - Travel plan	1	0.67	0	0.00	1	0.67
Section Total		12	8.00	9	6.00	9	6.00

Water							
		Max. Credit Points	Max. Credit Score [%]	Credit Points Achieved Project A	Credit Score Achieved Project A [%]	Credit Points Achieved Project B	Credit Score Achieved Project B [%]
Water	Wat 1 - Water consumption	5	3.33	2	1.33	2	1.33
	Wat 2 - Water monitoring	1	0.67	1	0.67	1	0.67
	Wat 3 - Water leak detection and prevention	2	1.33	0	0.00	1	0.67
	Wat 4 - Water efficient equipment	1	0.67	1	0.67	0	0.00
Section Total		9	6	4	2.67	4	2.67

Materials							
		Max. Credit Points	Max. Credit Score [%]	Credit Points Achieved Project A	Credit Score Achieved Project A [%]	Credit Points Achieved Project B	Credit Score Achieved Project B [%]
Materials	Mat 1 - Life cycle impacts	6	6.82	3	3.41	3	3.41
	Mat 3 - Responsible sourcing of materials	3	3.41	1	1.14	1	1.14
	Mat 4 - Insulation	1	1.14	1	1.14	0	0.00
	Mat 5 - Designing for robustness	1	1.14	1	1.14	1	1.14
Section Total		11	12.5	6	6.82	5	5.68

Waste							
		Max. Credit Points	Max. Credit Score [%]	Credit Points Achieved Project A	Credit Score Achieved Project A [%]	Credit Points Achieved Project B	Credit Score Achieved Project B [%]
Waste	Wst 1 - Construction waste management	3	3.75	2	2.5	2	2.5
	Wst 2 - Recycled aggreagtes	1	1.25	0	0	1	1.25
	Wst 3 - Operational waste	1	1.25	1	1.25	1	1.25
	Wst 4 - Speculative floor and ceiling finishes	1	1.25	1	1.25	1	1.25
Section Total		6	7.5	4	5.00	5	6.25

Land Use and Ecology							
		Max. Credit Points	Max. Credit Score [%]	Credit Points Achieved Project A	Credit Score Achieved Project A [%]	Credit Points Achieved Project B	Credit Score Achieved Project B [%]
Land Use and Ecology	Le 1 - Site Selection	3	3.00	2	2.00	2	2.00
	Le 2 - Ecological value of site and protection of ecological features	2	2.00	2	2.00	2	2.00
	Le 4 - Enhancing site ecology	3	3.00	2	2.00	0	0.00
	Le 5 - Long term impact on biodiversity	2	2.00	0	0.00	0	0.00
Section Total		10	10	6	6.00	4	4.00

Pollution							
		Max. Credit Points	Max. Credit Score [%]	Credit Points Achieved Project A	Credit Score Achieved Project A [%]	Credit Points Achieved Project B	Credit Score Achieved Project B [%]
Pollution	Pol 1 - Impact of refrigerants	4	2.86	2	1.43	3	2.14
	Pol 2 - Nox emissions	3	2.14	1	0.71	1	0.71
	Pol 3 - Surface water run-off	5	3.57	3	2.14	3	2.14
	Pol 4 - Reduction of night time light pollution	1	0.71	1	0.71	1	0.71
	Pol 5 - Noise attenuation	1	0.71	1	0.71	1	0.71
Section Total		14	10	8	5.71	9	6.43

	Max. Credit Points	Max. Certification Score	Credit Points Project A	Certification Score Project A	Credit Points Project B	Certification Score Project B
Total System Score	127.00	100.00	67	54.36	74	59.78

Table 16 LEED 2009 Core & Shell – Scenario 0

Sustainable Sites							
		Max. Credit Points	Max. Credit Score [%]	Credit Points Achieved Project A	Credit Score Achieved Project A [%]	Credit Points Achieved Project B	Credit Score Achieved Project B [%]
Sustainable Sites	SSp1 Construction Activity Pollution Prevention	Preq.	Preq.	Preq.	Preq.	Preq.	Preq.
	SSc1 Site Selection	1	1	1	1	1	1
	SSc2 Development Density and Community	5	5	5	5	5	5
	SSc3 Brownfield Redevelopment	1	1	0	0	0	0
	SSc4.1 Alternative Transport - Public Transport Access	6	6	6	6	6	6

	SSc4.2 Alternative Transport - Bicycle Storage and Changing Rooms	**2**	**2**	**0**	**0**	**2**	**2**
	SSc4.3 Alternative Transport - Low-Emitting and Fuel Efficient Vehicles	**3**	**3**	**3**	**3**	**3**	**3**
	SSc4.4 Alternative Transport - Parking Capacity	**2**	**2**	**2**	**2**	**2**	**2**
	SSc5.1 Site Development - Protect or Restore Habitat	**1**	**1**	**0**	**0**	**0**	**0**
	SSc5.2 Site Development - Maximize Open Space	**1**	**1**	**0**	**0**	**0**	**0**
	SSc6.1 Stormwater Design - Quantity Control	**1**	**1**	**0**	**0**	**0**	**0**

	SSc6.2 Stormwater Design - Quality Control	**1**	**1**	**0**	**0**	**0**	**0**
	SSc7.1 Heat Island Effect - Non-roof	**1**	**1**	**1**	**1**	**1**	**1**
	SSc7.2 Heat Island Effect - Roof	**1**	**1**	**0**	**0**	**0**	**0**
	SSc8 Light Pollution Redution	**1**	**1**	**1**	**1**	**0**	**0**
	SSc9 Tenant Design&Construction Guidelines	**1**	**1**	**1**	**1**	**1**	**1**
Section Total		**28**	**28**	**20**	**20.00**	**21**	**21.00**

Water Efficiency								
Water Efficiency		Max. Credit Points	Max. Credit Score [%]	Credit Points Achieved Project A	Credit Score Achieved Project A [%]	Credit Points Achieved Project B	Credit Score Achieved Project B [%]
	WEp1 Water Use Reduction - 20% Reduction	Preq.	Preq.	Preq.	Preq.	Preq.	Preq.
	WEc1 Water Efficient Landscaping	4	4	2	2	4	4
	WEc2 Innovative Wastewater Technologies	2	2	0	0	0	0
	WEc3 Water Use Reduction	4	4	3	3	0	0
Section Score		10	10	5	5.00	4	4.00

Energy & Atmosphere								
		Max. Credit Points	Max. Credit Score [%]	Credit Points Achieved Project A	Credit Score Achieved Project A [%]	Credit Points Achieved Project B	Credit Score Achieved Project B [%]
Energy & Atmosphere	EAp1 Fundamental Commissioning of Building Energy Systems***	Preq.	Preq.	Preq.	Preq.	Preq.	Preq.
	EAp2 Minimum Energy Performance	Preq.	Preq.	Preq.	Preq.	Preq.	Preq.
	EAp3 Fundamental Refrigerant Management	Preq.	Preq.	Preq.	Preq.	Preq.	Preq.
	EAc1 Optimize Energy Performance	21	21	17	17	18	18
	EAc2 On-Site Renewable Energy	4	4	0	0	0	0
	EAc3 Enhanced Commissioning	2	2	0	0	0	0
	EAc4 Enhanced Refrigerant Management	2	2	2	2	2	2

Energy & Atmosphere							
		Max. Credit Points	Max. Credit Score [%]	Credit Points Achieved Project A	Credit Score Achieved Project A [%]	Credit Points Achieved Project B	Credit Score Achieved Project B [%]
	EAc5.1 Measurement and Verification - Base Building	3	3	3	3	3	3
	EAc5.2 Measurement and Verification - Tenant Submetering	3	3	0	0	3	3
	EAc6 Green Power	2	2	0	0	0	0
Section Score		37	37	22	22.00	26	26.00

Materials and Resources								
		Max. Credit Points	Max. Credit Score [%]	Credit Points Achieved Project A	Credit Score Achieved Project A [%]	Credit Points Achieved Project B	Credit Score Achieved Project B [%]
Materials and Resources	MRp1 Storage and Collection of Recyclables	Preq.	Preq.	Preq.	Preq.	Preq.	Preq.
	MRc1 Building Reuse - Maintain Existing Walls, Floors and Roof	5	5	0	0	2	2
	MRc2 Construction Waste Management	2	2	2	2	1	1
	MRc3 Materials Reuse	1	1	0	0	0	0
	MRc4 Recycled Content	2	2	2	2	1	1
	MRc5 Regional Materials	2	2	2	2	1	1
	MRc6 Certified Wood	1	1	0	0	0	0
Section Score		13	13	6	6.00	5	5.00

Indoor Environmental Quality							
		Max. Credit Points	Max. Credit Score [%]	Credit Points Achieved Project A	Credit Score Achieved Project A [%]	Credit Points Achieved Project B	Credit Score Achieved Project B [%]
Indoor Environmental Quality	IEQp1 Minimum Indoor Air Quality Performance	Preq.	Preq.	Preq.	Preq.	Preq.	Preq.
	IEQp2 Environmental Tobacco Smoke (ETS) Control	Preq.	Preq.	Preq.	Preq.	Preq.	Preq.
	IEQc1 Outdoor Air Delivery Monitoring	1	1	0	0	0	0
	IEQc2 Increased Ventilation	1	1	0	0	0	0
	IEQc3 Construction IAQ Management Plan - During Construction	1	1	1	1	0	0

Indoor Environmental Quality							
		Max. Credit Points	Max. Credit Score [%]	Credit Points Achieved Project A	Credit Score Achieved Project A [%]	Credit Points Achieved Project B	Credit Score Achieved Project B [%]
	IEQc4.1 Low-Emitting-Materials - Adhesives ans Sealants	1	1	1	1	0	0
	IEQc4.2 Low-Emitting-Materials - Paints and Coatings	1	1	1	1	0	0
	IEQc4.3 Low-Emitting-Materials - Flooring Systems	1	1	0	0	1	1
	IEQc4.4 Low-Emitting-Materials - Composite Wood and Agrifiber Products	1	1	0	0	0	0
	IEQc5 Indoor Chemical and Pollutant Source Control	1	1	0	0	0	0

Indoor Environmental Quality								
		Max. Credit Points	Max. Credit Score [%]	Credit Points Achieved Project A	Credit Score Achieved Project A [%]	Credit Points Achieved Project B	Credit Score Achieved Project B [%]
	IEQc6 Controllability of Systems - Thermal Comfort	1	1	1	1	1	1
	IEQc7 Thermal Comfort - Design	1	1	1	1	0	0
	IEQc8.1 Daylight and Views - Daylight	1	1	0	0	0	0
	IEQc8.2 Daylight and Views - Views	1	1	0	0	0	0
Section Score		12	12	5	5.00	2	2.00

	Max. Credit Points	Max. Certification Score	Credit Points Project A	Certification Score Project A	Credit Points Project B	Certification Score Project B
Total System Score	100	100	58	58	58	58

Appendix A

Table 17 BREEAM International 2013, Project A

Energy

	Project A Credit Points Achieved					
	Credtis by Assessor	Credits by Definition	Credit Score Scenario A	Credit Score Scenario B	Credit Score Scenario C1	Credit Score Scenario C2
Ene 1 - Reduction of CO2 emissions	10	37.04	16.70	5.67	8.22	6.17
Ene 2 - Energy monitoring	2	7.41	3.34	1.13	1.64	1.23
Ene 3 - External Lighting	1	3.70	1.67	0.57	0.82	0.62
Ene 4 - Low and zero carbon technologies	1	3.70	1.67	0.57	0.82	0.62
Ene 5 - Energy efficient cold storage	2	7.41	3.34	1.13	1.64	1.23
Ene 6 - Energy efficient tranportation systems	1	3.70	1.67	0.57	0.82	0.62
Ene 8 - Energy efficient equipment	0	0.00	0.00	0.00	0.00	0.00
Section Total	**17**	**62.96**	**28.40**	**9.63**	**13.98**	**10.50**

Water						
	Project A, Credit Points Achieved					
	Credits by Assessor	Credits by Definition	Credit Score Scenario A	Credit Score Scenario B	Credit Score Scenario C1	Credit Score Scenario C2
Wat 1 - Water consump-tion	2	22.22	1.67	5.22	0.56	3.70
Wat 2 - Water monitoring	1	11.11	0.83	2.61	0.28	1.85
Wat 3 - Water leak detection and prevention	0	0.00	0.00	0.00	0.00	0.00
Wat 4 - Water efficient equipment	1	11.11	0.83	2.61	0.28	1.85
Section Total	4	44.44	3.33	10.44	1.11	7.41

Materials

Project A, Credit Points Achieved						
	Credits by Assessor	Credits by Definition	Credit Score Scenario A	Credit Score Scenario B	Credit Score Scenario C1	Credit Score Scenario C2
Mat 1 - Life cycle impacts	3	27.27	7.04	6.41	1.85	4.55
Mat 3 - Responsible sourcing of materials	1	9.09	2.35	2.14	0.62	1.52
Mat 4 - Insulation	1	9.09	2.35	2.14	0.62	1.52
Mat 5 - Designing for robustness	1	9.09	2.35	2.14	0.62	1.52
Section Total	**6**	**54.55**	**14.07**	**12.82**	**3.71**	**9.09**

Waste

	Project A, Credit Points Achieved					
	Credits by Assessor	Credits by Definition	Credit Score Scenario A	Credit Score Scenario B	Credit Score Scenario C1	Credit Score Scenario C2
Wst 1 - Construction waste management	2	33.33	1.43	2.37	2.27	5.56
Wst 2 - Recycled aggreagtes	0	0.00	0.00	0.00	0.00	0.00
Wst 3 - Operational waste	1	16.67	0.72	1.18	1.13	2.78
Wst 4 - Speculative floor and ceiling finishes	1	16.67	0.72	1.18	1.13	2.78
Section Total	**4**	**66.67**	**2.87**	**4.73**	**4.53**	**11.11**

Site Selection						
Project A, Credit Points Achieved						
	Credits by Assessor	Credits by Definition	Credit Score Scenario A	Credit Score Scenario B	Credit Score Scenario C1	Credit Score Scenario C2
Le 1 - Site Selection	**2**	**9.09**	**1.29**	**2.14**	**4.45**	**1.52**
Le 2 - Ecological value of site and protection of ecological features	**2**	**9.09**	**1.29**	**2.14**	**4.45**	**1.52**
Le 4 - Enhancing site ecology	**2**	**9.09**	**1.29**	**2.14**	**4.45**	**1.52**
Le 5 - Long term impact on biodiversity	**0**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Tra 1 - Public transport availability	**3**	**13.64**	**1.94**	**3.20**	**6.67**	**2.27**
Tra 2 - Proximity to amenities	**2**	**9.09**	**1.29**	**2.14**	**4.45**	**1.52**
Tra 3 - Alternative modes of transport	**2**	**9.09**	**1.29**	**2.14**	**4.45**	**1.52**
Tra 4 - Maximum car parking capacity	**2**	**9.09**	**1.29**	**2.14**	**4.45**	**1.52**
Tra 5 - Travel plan	**0**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**

Site Selection						
Project A, Credit Points Achieved						
	Credits by Assessor	Credits by Definition	Credit Score Scenario A	Credit Score Scenario B	Credit Score Scenario C1	Credit Score Scenario C2
Section Total	**15**	**50.00**	**9.68**	**16.02**	**33.34**	**11.37**

Other Credits (grouped)

Project A,
Credit Points Achieved

	Credits by Assessor	Credits by Definition	Credit Score Scenario A	Credit Score Scenario B	Credit Score Scenario C1	Credit Score Scenario C2
Management						
Man 1 - Sustainable Procurement	4	7.69	0.24	0.55	0.98	1.28
Man 2 - Responsible construction practices	1	1.92	0.06	0.14	0.25	0.32
Man 3 - Construction Site Impacts	1	1.92	0.06	0.14	0.25	0.32
Man 4 - Stakeholder participation	1	1.92	0.06	0.14	0.25	0.32
Man 5 - Life Cycle cost and service life planning	0	0.00	0.00	0.00	0.00	0.00
Health & Wellbeing						
Hea 1 - Visual Comfort	1	1.92	0.06	0.14	0.25	0.32

Other Credits (grouped)

Project A, Credit Points Achieved

	Credits by Assessor	Credits by Definition	Credit Score Scenario A	Credit Score Scenario B	Credit Score Scenario C1	Credit Score Scenario C2
Hea 2 - Indoor air quality	2	3.85	0.12	0.27	0.49	0.64
Hea 3 - Thermal comfort	2	3.85	0.12	0.27	0.49	0.64
Hea 4 - Water quality	0	0.00	0.00	0.00	0.00	0.00
Hea 5 - Acoustic performance	1	1.92	0.06	0.14	0.25	0.32
Hea 6 - Safe access	0	0.00	0.00	0.00	0.00	0.00
Hea 7 - Hazards	0	0.00	0.00	0.00	0.00	0.00
Pollution						
Pol 1 - Impact of refrigerants	2	3.85	0.12	0.27	0.49	0.64
Pol 2 - Nox emissions	1	1.92	0.06	0.14	0.25	0.32
Pol 3 - Surface water run-off	3	5.77	0.18	0.41	0.74	0.96
Pol 4 - Reduction of night time light pollution	1	1.92	0.06	0.14	0.25	0.32
Pol 5 - Noise attenuation	1	1.92	0.06	0.14	0.25	0.32

Other Credits (grouped)

	Project A, Credit Points Achieved					
	Credits by Assessor	Credits by Definition	Credit Score Scenario A	Credit Score Scenario B	Credit Score Scenario C1	Credit Score Scenario C2
Total Other Credits (grouped)*	21	40.38	1.25	2.87	5.17	6.73

	Credit Points Achieved		Certification Score Scenario A	Certification Score Scenario B	Certification Score Scenario C1	Certification Score Scenario C2
Total System Score	67		59.60	56.52	61.84	56.21

Table 18 LEED Core & Shell v3 (2009), Project A

Site Selection						
Project A, Credit Points Achieved						
	Credits by Assessor	Credits by Definition	Credit Score Scenario A	Credit Score Scenario B	Credit Score Scenario C1	Credit Score Scenario C2
SSc1 Site Selection	1	3.85	0.55	0.90	1.88	0.64
SSC2 Development Density and Community	5	19.23	2.73	4.52	9.40	3.21
SSc3 Brownfield Redevelopment	0	0.00	0.00	0.00	0.00	0.00
SSc4.1 Alternative Transport - Public Transport Access	6	23.08	3.28	5.42	11.28	3.85
SSc4.2 Alternative Transport - Bicycle Storage and Changing Rooms	0	0.00	0.00	0.00	0.00	0.00
SSc4.3 Alternative Transport - Low-Emitting and Fuel Efficient Vehicles	3	11.54	1.64	2.71	5.64	1.92
SSc4.4 Alternative Transport - Parking Capacity	2	7.69	1.09	1.81	3.76	1.28
SSc5.1 Site Development - Protect or Restore Habitat	0	0.00	0.00	0.00	0.00	0.00

SSc5.2 Site Development - Maximize Open Space	**0**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
SSc6.1 Stormwater Design - Quantity Control	**0**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
SSc6.2 Stormwater Design - Quality Control	**0**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
SSc7.1 Heat Island Effect - Non-roof	**1**	**3.85**	**0.55**	**0.90**	**1.88**	**0.64**
SSc7.2 Heat Island Effect - Roof	**0**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Section Score	**18**	**69.23**	**9.83**	**16.27**	**33.85**	**11.54**

Water Efficiency						
Project A, Credit Points Achieved						
	Credits by Assessor	Credits by Definition	Credit Score Scenario A	Credit Score Scenario B	Credit Score Scenario C1	Credit Score Scenario C2
WEp1 Water Use Reduction - 20% Reduction	Preq.	Preq.	Preq.	Preq.	Preq.	Preq.
WEc1 Water Efficient Landscaping	2	20	1.50	4.70	0.50	3.33
WEc2 Innovative Wastewater Technologies	0	0	0.00	0.00	0.00	0.00
WEc3 Water Use Reduction	3	30	2.25	7.05	0.75	5.00
Section Score	5	50	3.75	11.75	1.25	8.34

Energy & Atmosphere						
Project A, Credit Points Achieved						
	Credits by Assessor	Credits by Definition	Credit Score Scenario A	Credit Score Scenario B	Credit Score Scenario C1	Credit Score Scenario C2
EAp2 Minimum Energy Performance	Preq.	Preq.	Preq.	Preq.	Preq.	Preq.
EAc1 Optimize Energy Performance	17	48.57	21.91	7.43	10.78	8.10
EAc2 On-Site Renewable Energy	0	0.00	0.00	0.00	0.00	0.00
EAc3 Enhanced Commissioning	0	0.00	0.00	0.00	0.00	0.00
EAc5.1 Measurement and Verification - Base Building	3	8.57	3.87	1.31	1.90	1.43
EAc5.2 Measure-ment and Verification - Tenant Submetering	0	0.00	0.00	0.00	0.00	0.00
EAc6 Green Power	0	0.00	0.00	0.00	0.00	0.00
Section Score	**20**	**57.14**	**25.77**	**8.74**	**12.69**	**9.53**

Materials and Resources						
Project A, Credit Points Achieved						
	Credits by Assessor	Credits by Definition	Credit Score Scenario A	Credit Score Scenario B	Credit Score Scenario C1	Credit Score Scenario C2
MRc1 Building Reuse - Maintain Existing Walls, Floors and Roof	0	0.00	0.00	0.00	0.00	0.00
MRc3 Materials Reuse	0	0.00	0.00	0.00	0.00	0.00
MRc4 Recycled Content	2	18.18	4.69	4.27	1.24	3.03
MRc5 Regional Materials	2	18.18	4.69	4.27	1.24	3.03
MRc6 Certified Wood	0	0.00	0.00	0.00	0.00	0.00
Section Score	4	36.36	9.38	8.55	2.47	6.06

Waste

Project A, Credit Points Achieved						
	Credits by Assessor	Credits by Definition	Credit Score Scenario A	Credit Score Scenario B	Credit Score Scenario C1	Credit Score Scenario C2
MRp1 Storage and Collection of Recycables	Preq.	Preq.	Preq.	Preq.	Preq.	Preq.
MRc2 Construction Waste Management	2	100	4.3	7.1	6.8	16.67
Section Score	2	100	4.3	7.1	6.8	16.67

Others Credits Group						
	Project A, Credit Points Achieved					
	Credits by Assessor	Credits by Definition	Credit Score Scenario A	Credit Score Scenario B	Credit Score Scenario C1	Credit Score Scenario C2
Indoor Environmental Quality						
IEQp1 Minimum Indoor Air Quality Performance	Preq.	Preq.	Preq.	Preq.	Preq.	Preq.
IEQp2 Environmental Tobacco Smoke (ETS) Control	Preq.	Preq.	Preq.	Preq.	Preq.	Preq.
IEQc1 Outdoor Air Delivery Monitoring	0	0.00	0.00	0.00	0.00	0.00
IEQc2 Increased Ventilation	0	0.00	0.00	0.00	0.00	0.00
IEQc3 Construction IAQ Management Plan - During Construction	1	6.25	0.19	0.44	0.8	1.04
IEQc4.1 Low-Emitting-Materials - Adhesives ans Sealants	1	6.25	0.19	0.44	0.8	1.04
IEQc4.2 Low-Emitting-	1	6.25	0.19	0.44	0.8	0.00

Others Credits Group						
	Project A, Credit Points Achieved					
	Credits by Assessor	Credits by Definition	Credit Score Scenario A	Credit Score Scenario B	Credit Score Scenario C1	Credit Score Scenario C2
Materials - Paints and Coatings						
IEQc4.3 Low-Emitting-Materials - Flooring Systems	0	0.00	0.00	0.00	0.00	0.00
IEQc4.4 Low-Emitting-Materials - Composite Wood and Agrifiber Products	0	0.00	0.00	0.00	0.00	0.00
IEQc5 Indoor Chemical and Pollutant Source Control	0	0.00	0.00	0.00	0.00	0.00
IEQc6 Controllability of Systems - Thermal Comfort	1	6.25	0.19	0.44	0.8	1.04
IEQc7 Thermal Comfort - Design	1	6.25	0.19	0.44	0.8	1.04
IEQc8.1 Daylight and Views – Daylight	0	0.00	0.00	0.00	0.00	0.00

Others Credits Group						
	Project A, Credit Points Achieved					
	Credits by Assessor	Credits by Definition	Credit Score Scenario A	Credit Score Scenario B	Credit Score Scenario C1	Credit Score Scenario C2
IEQc8.2 Daylight and Views - Views	0	0.00	0.00	0.00	0.00	0.00
Management						
SSp1 Construction Activity Pollution Prevention	Preq.	Preq.	Preq.	Preq.	Preq.	Preq.
SSc9 Tenant Design&Con-struction Guidelines	1	6.25	0.19	0.44	0.8	1.04
EAp1 Fundamental Commissioning of Building Energy Systems	Preq.	Preq.	Preq.	Preq.	Preq.	Preq.
Pollution						
SSc8 Light Pollution Redution	1	6.25	0.19	0.44	0.8	1.04
EAp3 Fundamental Refrigerant Management	Preq.	Preq.	Preq.	Preq.	Preq.	Preq.
EAc4 Enhanced Refrigerant Management	2	12.5	0.39	0.89	1.6	2.08

Others Credits Group						
	Project A, Credit Points Achieved					
	Credits by Assessor	Credits by Definition	Credit Score Scenario A	Credit Score Scenario B	Credit Score Scenario C1	Credit Score Scenario C2
Section Score	9	56.25	1.74	3.99	7.2	9.38

	Credit Points Achieved		Certification Score Scenario A	Certification Score Scenario B	Certification Score Scenario C1	Certification Score Scenario C2
Total System Score	58		54.78	56.40	64.26	61.51

Appendix B

Table 19 BREEAM International 2013, Project B

Site Selection						
	Project B, Credit Points Achieved					
	Credits by Assessor	Credits by Definition	Credit Score Scenario A	Credit Score Scenario B	Credit Score Scenario C1	Credit Score Scenario C2
Le 1 - Site Selection	2	9.09	1.29	2.14	4.45	1.52
Le 2 - Ecological value of site and protection of ecological features	2	9.09	1.29	2.14	4.45	1.52
Le 4 - Enhancing site ecology	0	0.00	0.00	0.00	0.00	0.00
Le 5 - Long term impact on biodiversity	0	0.00	0.00	0.00	0.00	0.00
Tra 1 - Public transport availability	3	13.64	1.94	3.20	6.67	2.27
Tra 2 - Proximity to amenities	2	9.09	1.29	2.14	4.45	1.52
Tra 3 - Alternative modes of transport	2	9.09	1.29	2.14	4.45	1.52

Tra 4 - Maximum car parking capacity	1	4.55	0.65	1.07	2.22	0.76
Tra 5 - Travel plan	1	4.55	0.65	1.07	2.22	0.76
Section Total	**13**	**40.91**	**8.39**	**13.89**	**28.90**	**9.85**

Water

	Project B, Credit Points Achieved					
	Credits by Assessor	Credits by Definition	Credit Score Scenario A	Credit Score Scenario B	Credit Score Scenario C1	Credit Score Scenario C2
Wat 1 - Water consump-tion	2	22.22	1.67	5.22	0.56	3.70
Wat 2 - Water monitoring	1	11.11	0.83	2.61	0.28	1.85
Wat 3 - Water leak detection and prevention	1	11.11	0.83	2.61	0.28	1.85
Wat 4 - Water efficient equipment	0	0.00	0.00	0.00	0.00	0.00
Section Total	4	44.44	3.33	10.44	1.11	7.41

Energy

Project B Credit Points Achieved	Credtis by Assessor	Credits by Definition	Credit Score Scenario A	Credit Score Scenario B	Credit Score Scenario C1	Credit Score Scenario C2
Ene 1 - Reduction of CO2 emissions	5	18.52	8.35	2.83	4.11	3.09
Ene 2 - Energy monitoring	2	7.41	3.34	1.13	1.64	1.23
Ene 3 - External Lighting	1	3.70	1.67	0.57	0.82	0.62
Ene 4 - Low and zero carbon technologies	4	14.81	6.68	2.27	3.29	2.47
Ene 5 - Energy efficient cold storage	1	3.70	1.67	0.57	0.82	0.62
Ene 6 - Energy efficient tranportation systems	1	3.70	1.67	0.57	0.82	0.62
Ene 8 - Energy efficient equipment	1	3.70	1.67	0.57	0.82	0.62
Section Total	**15**	**55.56**	**25.06**	**8.50**	**12.33**	**9.26**

Materials

	Project B, Credit Points Achieved					
	Credits by Assessor	Credits by Definition	Credit Score Scenario A	Credit Score Scenario B	Credit Score Scenario C1	Credit Score Scenario C2
Mat 1 - Life cycle impacts	3	27.27	7.04	6.41	1.85	4.55
Mat 3 - Responsible sourcing of materials	1	9.09	2.35	2.14	0.62	1.52
Mat 4 - Insulation	0	0.00	0.00	0.00	0.00	0.00
Mat 5 - Designing for robustness	1	9.09	2.35	2.14	0.62	1.52
Section Total	**5**	**45.45**	**11.73**	**10.68**	**3.09**	**7.58**

Waste

	Project B, Credit Points Achieved					
	Credits by Assessor	Credits by Definition	Credit Score Scenario A	Credit Score Scenario B	Credit Score Scenario C1	Credit Score Scenario C2
Wst 1 - Construction waste management	2	33.33	1.43	2.37	2.27	5.56
Wst 2 - Recycled aggreagtes	1	16.67	0.72	1.18	1.13	2.78
Wst 3 - Operational waste	1	16.67	0.72	1.18	1.13	2.78
Wst 4 - Speculative floor and ceiling finishes	1	16.67	0.72	1.18	1.13	2.78
Section Total	**5**	**83.33**	**3.58**	**5.92**	**5.67**	**13.89**

Other Credits (grouped)

	Project B, Credit Points Achieved					
	Credits by Assessor	Credits by Definition	Credit Score Scenario A	Credit Score Scenario B	Credit Score Scenario C1	Credit Score Scenario C2
Management						
Man 1 - Sustainable Procurement	4	7.69	0.24	0.55	0.98	1.28
Man 2 - Responsible construction practices	1	1.92	0.06	0.14	0.25	0.32
Man 3 - Construction Site Impacts	2	3.85	0.12	0.27	0.49	0.64
Man 4 - Stakeholder participation	2	3.85	0.12	0.27	0.49	0.64
Man 5 - Life Cycle cost and service life planning	3	5.77	0.18	0.1	0.74	0.96
Health & Wellbeing						
Hea 1 - Visual Comfort	2	3.85	0.12	0.27	0.49	0.64
Hea 2 - Indoor air quality	3	5.77	0.18	0.41	0.74	0.96

Hea 3 - Thermal comfort	2	3.85	0.12	0.27	0.49	0.64
Hea 4 - Water quality	1	1.92	0.06	0.14	0.25	0.32
Hea 5 - Acoustic performance	2	3.85	0.12	0.27	0.49	0.64
Hea 6 - Safe access	1	1.92	0.06	0.14	0.25	0.32
Hea 7 - Hazards	0	0.00	0.00	0.00	0.00	0.00
Pollution						
Pol 1 - Impact of refrigerants	3	5.77	0.18	0.41	0.74	0.96
Pol 2 - Nox emissions	1	1.92	0.06	0.14	0.25	0.32
Pol 3 - Surface water run-off	3	5.77	0.18	0.41	0.74	0.96
Pol 4 - Reduction of night time light pollution	1	1.92	0.06	0.14	0.25	0.32
Pol 5 - Noise attenuation	1	1.92	0.06	0.14	0.25	0.32
Total Other Credits (grouped)*	**32**	**61.54**	**1.91**	**4.37**	**7.88**	**10.26**

	Credit Points Achieved		Certification Score Scenario A	Certification Score Scenario B	Certification Score Scenario C1	Certification Score Scenario C2
Total System Score	74		54.00	53.80	58.97	58.25

Table 20 LEED Core & Shell v3 (2009), Project B

Site Selection						
	Project B, Credit Points Achieved					
	Credits by Assessor	Credits by Definition	Credit Score Scenario A	Credit Score Scenario B	Credit Score Scenario C1	Credit Score Scenario C2
SSc1 Site Selection	1	3.85	0.55	0.90	1.88	0.64
SSC2 Development Density and Community	5	19.23	2.73	4.52	9.40	3.21
SSc3 Brownfield Redevelopment	0	0.00	0.00	0.00	0.00	0.00
SSc4.1 Alternative Transport - Public Transport Access	6	23.08	3.28	5.42	11.28	3.85
SSc4.2 Alternative Transport - Bicycle Storage and Changing Rooms	2	7.69	1.09	1.81	3.76	1.28
SSc4.3 Alternative Transport - Low-Emitting and Fuel Efficient Vehicles	3	11.54	1.64	2.71	5.64	1.92
SSc4.4 Alternative Transport - Parking Capacity	2	7.69	1.09	1.81	3.76	1.28
SSc5.1 Site Development - Protect or Restore Habitat	0	0.00	0.00	0.00	0.00	0.00

SSc5.2 Site Development - Maximize Open Space	**0**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
SSc6.1 Stormwater Design - Quantity Control	**0**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
SSc6.2 Stormwater Design - Quality Control	**0**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
SSc7.1 Heat Island Effect - Non-roof	**1**	**3.85**	**0.55**	**0.90**	**1.88**	**0.64**
SSc7.2 Heat Island Effect - Roof	**0**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Section Score	**20**	**76.92**	**10.92**	**18.08**	**37.62**	**12.82**

Water Efficiency						
Project B, Credit Points Achieved						
	Credits by Assessor	Credits by Definition	Credit Score Scenario A	Credit Score Scenario B	Credit Score Scenario C1	Credit Score Scenario C2
WEp1 Water Use Reduction - 20% Reduction	Preq.	Preq.	Preq.	Preq.	Preq.	Preq.
WEc1 Water Efficient Landscaping	4	40	3	9.4	1	6.67
WEc2 Innovative Wastewater Technologies	0.00	0.00	0.00	0.00	0.00	0.00
WEc3 Water Use Reduction	0.00	0.00	0.00	0.00	0.00	0.00
Section Score	4	40	3	9.4	1	6.67

Energy & Atmosphere						
Project B, Credit Points Achieved						
	Credits by Assessor	Credits by Definition	Credit Score Scenario A	Credit Score Scenario B	Credit Score Scenario C1	Credit Score Scenario C2
EAp2 Minimum Energy Performance	Preq.	Preq.	Preq.	Preq.	Preq.	Preq.
EAc1 Optimize Energy Performance	18	51.43	23.19	7.87	11.42	8.57
EAc2 On-Site Renewable Energy	0	0.00	0.00	0.00	0.00	0.00
EAc3 Enhanced Commissioning	0	0.00	0.00	0.00	0.00	0.00
EAc5.1 Measurement and Verification - Base Building	3	8.57	3.87	1.31	1.90	1.43
EAc5.2 Measurement and Verification - Tenant Submetering	3	8.57	3.87	1.31	1.90	1.43
EAc6 Green Power	0	0.00	0.00	0.00	0.00	0.00
Section Score	**24**	**68.57**	**30.93**	**10.49**	**15.22**	**11.43**

Materials and Resources						
Project B, Credit Points Achieved						
	Credits by Assessor	Credits by Definition	Credit Score Scenario A	Credit Score Scenario B	Credit Score Scenario C1	Credit Score Scenario C2
MRc1 Building Reuse - Maintain Existing Walls, Floors and Roof	2	18.18	4.69	4.27	1.24	3.03
MRc3 Materials Reuse	0.00	0.00	0.00	0.00	0.00	0.00
MRc4 Recycled Content	1	9.09	2.35	2.14	0.62	1.52
MRc5 Regional Materials	1	9.09	2.35	2.14	0.62	1.52
MRc6 Certified Wood	0.00	0.00	0.00	0.00	0.00	0.00
Section Score	**4**	**36.36**	**9.38**	**8.55**	**2.47**	**6.06**

Waste

Project B, Credit Points Achieved						
	Credits by Assessor	Credits by Definition	Credit Score Scenario A	Credit Score Scenario B	Credit Score Scenario C1	Credit Score Scenario C2
MRp1 Storage and Collection of Recyclables	Preq.	Preq.	Preq.	Preq.	Preq.	Preq.
MRc2 Construction Waste Management	1	50	2.15	3.55	3.4	8.34
Section Score	1	50	2.15	3.55	3.4	8.34

Others Credits Group

Project B, Credit Points Achieved						
	Credits by Assessor	Credits by Definition	Credit Score Scenario A	Credit Score Scenario B	Credit Score Scenario C1	Credit Score Scenario C2
Indoor Environmental Quality						
IEQp1 Minimum Indoor Air Quality Performance	Preq.	Preq.	Preq.	Preq.	Preq.	Preq.
IEQp2 Environmental Tobacco Smoke (ETS) Control	Preq.	Preq.	Preq.	Preq.	Preq.	Preq.
IEQc1 Outdoor Air Delivery Monitoring	0	0.00	0.00	0.00	0.00	0.00
IEQc2 Increased Ventilation	0	0.00	0.00	0.00	0.00	0.00
IEQc3 Construction IAQ Management Plan - During Construction	0	0.00	0.00	0.00	0.00	0.00
IEQc4.1 Low-Emitting-Materials - Adhesives and Sealants	0	0.00	0.00	0.00	0.00	0.00
IEQc4.2 Low-Emitting-	0	0.00	0.00	0.00	0.00	0.00

Materials - Paints and Coatings						
IEQc4.3 Low-Emitting-Materials - Flooring Systems	1	6.25	0.00	0.44	0.8	1.04
IEQc4.4 Low-Emitting-Materials - Composite Wood and Agrifiber Products	0	0.00	0.00	0.00	0.00	0.00
IEQc5 Indoor Chemical and Pollutant Source Control	0	0.00	0.00	0.00	0.00	0.00
IEQc6 Controllability of Systems - Thermal Comfort	1	6.25	0.19	0.44	0.8	1.04
IEQc7 Thermal Comfort - Design	0	0.00	0.00	0.00	0.00	0.00
IEQc8.1 Daylight and Views - Daylight	0	0.00	0.00	0.00	0.00	0.00
IEQc8.2 Daylight and Views - Views	0	0.00	0.00	0.00	0.00	0.00
Management						
SSp1 Construction Activity Pollution Prevention	Preq.	Preq.	Preq.	Preq.	Preq.	Preq.

SSc9 Tenant Design&Con-struction Guidelines	1	6.25	0.19	0.44	0.8	1.04
EAp1 Fundamental Commissio-ning of Building Energy Systems	Preq.	Preq.	Preq.	Preq.	Preq.	Preq.
Pollution						
SSc8 Light Pollution Redution	0	0.00	0.00	0.00	0.00	0.00
EAp3 Fundamental Refrigerant Management	Preq.	Preq.	Preq.	Preq.	Preq.	Preq.
EAc4 Enhanced Refrigerant Management	2	12.5	0.39	0.89	1.6	2.08
Section Score	**5**	**31.25**	**0.97**	**2.22**	**4**	**5.2**

	Credit Points Achieved		Certification Score Scenario A	Certification Score Scenario B	Certification Score Scenario C1	Certification Score Scenario C2
Total System Score	58		57.35	52.28	63.71	50.53

Appendix Study Outcomes

Table 21 Outcomes Scenario A

		BREEAM International 2013 Scenario A		LEED 2009 Core & Shell Scenario A	
	Scenario A Weightings	Project A Section Score [%]	Project B Section Score [%]	Project A Section Score [%]	Project B Section Score [%]
Energy	45.10	28.40	25.06	25.77	30.93
Materials	25.80	14.07	11.73	9.38	9.38
Site Selection	14.20	9.68	8.39	9.83	10.92
Water	7.50	3.33	3.33	3.75	3.00
Waste	4.30	2.87	3.58	4.30	2.15
Other Credits	3.10	1.25	1.91	1.74	0.97
Total	**100.00**	**59.60**	**54.00**	**54.78**	**57.35**

Table 22 Outcomes Scenraio B

		BREEAM International 2013 Scenario B		LEED 2009 Core&Shell Scenario B	
	Scenario B Weightings	Project A Section Score [%]	Project B Section Score [%]	Project A Section Score [%]	Project B Section Score [%]
Site Selection	23.5	16.02	13.89	16.27	18.08
Materials	23.5	12.82	10.68	8.55	8.55
Water	23.5	9.63	8.50	8.74	10.49
Energy	15.3	4.73	5.92	7.10	3.55
Waste	7.1	10.44	10.44	11.75	9.40
Other Credits	7.1	2.87	4.37	3.99	2.22
Total	**100.00**	**56.52**	**53.80**	**56.40**	**52.28**

Table 23 Outcomes Scenario C1

		BREEAM International 2013 Scenario C1		LEED 2009 Core&Shell Scenario C1	
	Scenario C1 Weightings	Project A Section Score [%]	Project B Section Score [%]	Project A Section Score [%]	Project B Section Score [%]
Site Selection	48.9	33.34	28.90	33.85	37.62
Energy	22.2	13.98	12.33	12.69	15.22
Other Credits	12.8	5.17	7.88	7.20	4.00
Waste	6.8	4.53	5.67	6.80	3.40
Materials	6.8	3.71	3.09	2.47	2.47
Water	2.5	1.11	1.11	1.25	1.00
Total	**100.00**	**61.84**	**58.97**	**64.26**	**63.71**

Table 24 Outcomes Scenario C2

		BREEAM International 2013 Scenario C2		LEED 2009 Core&Shell Scenario C2	
	Scenario C2 Weightings	Project A Section Score [%]	Project B Section Score [%]	Project A Section Score [%]	Project B Section Score [%]
Site Selection	16.67	11.37	9.85	11.54	12.82
Materials	16.67	9.09	7.58	6.06	6.06
Water	16.67	7.41	7.41	8.34	6.67
Energy	16.67	10.50	9.26	9.53	11.43
Waste	16.67	11.11	13.89	16.67	8.34
Other Credits	16.67	6.73	10.26	9.38	5.21
Total	**100.0**	**56.21**	**58.25**	**61.51**	**50.53**