CRITERIA FOR THE SELECTION OF ECO-FRIENDLY MATERIALS IN INTERIOR ARCHITECTURE

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CRITERIA FOR THE SELECTION OF ECO-FRIENDLY MATERIALS IN INTERIOR ARCHITECTURE

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ABSTRACT

CRITERIA FOR THE SELECTION OF ECO-FRIENDLY MATERIALS IN INTERIOR ARCHITECTURE

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Environmentally responsible or sustainable design has become a fundamental issue in the field of Interior Architecture, as well as other disciplines. However, the implementation of sustainability in the practice of Interior Architecture is still limited, especially regarding the selection of eco–friendly materials. In this thesis, in order to achieve a higher level of sustainability in the construction industry, a classification system for the usage of eco-friendly materials in Interior Architecture was developed.

The study also includes developed guidelines, derived from the analysis of LEED Green Building Rating System and various studies in literature, regarding choosing eco-friendly materials. The criteria set out and the developed classification system for materials will be benefitted for providing a cleaner and healthier environment. By the use of these guidelines, excessive consumption of natural resources, as well as possible harmful emissions are aimed to be reduced.

Keywords: Eco-Friendly Materials, Green Building Materials, Environmentally Responsible Design, Classification System for Eco-Friendly Materials

ÖZET

İÇ MİMARLIKTA KULLANILAN ÇEVRE DOSTU MALZEMELERİN SEÇİM KRİTERLERİ

Wesam Awad Ali ABDELSLAM
Yüksek Lisans, İç Mimarlık Anabilim Dalı
Tez Yöneticisi: Y. Doç. Dr. Özge SÜZER

Şubat 2017,56 sayfa

Başka disiplinlerde olduğu gibi, çevreye duyarlı veya sürdürülebilir tasarım, İç Mimarlık alanında da temel bir konu haline gelmiştir. Ancak, İç Mimarlık uygulamalarına sürdürülebilirliğin entegre edilmesi, özellikle çevre dostu malzemelerin seçilmesi bağlamında halen kısıtlıdır. Bu tez çalışması kapsamında, yapı sektöründe daha yüksek seviyede sürdürülebilirlik sağlayabilmek amacıyla İç Mimarlık alanında kullanılan çevre dostu malzemeler için bir sınıflandırma sistemi geliştirilmiştir.

Bu çalışma aynı zamanda, LEED Yeşil Bina Sertifika Sisteminin ve literatürdeki çeşitli kaynakların analizi ile ortaya konan, doğa dostu malzemelerin seçilmesine ilişkin kılavuz ilkeleri de içermektedir. Belirlenen kriterler ve malzemeler için geliştirilen bu sınıflandırma sisteminden, daha temiz ve sağlıklı bir çevrenin sağlanabilmesi için faydalanılacaktır. Kılavuz ilkelerin kullanımı ile, doğal kaynakların aşırı tüketimi ve olası zararlı gaz salınımlarının azaltılması hedeflenmektedir.

Anahtar Kelimeler: Çevre Dostu Malzemeler, Yeşil Bina Malzemeleri, Çevreye Duyarlı Tasarım, Doğa Dostu Malzemeler için Sınıflandırma Sistemi

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LIST OF ABBREVIATIONS

BREEAM	Building Research Establishment Environmental Assessment Methodology
CASBEE	Comprehensive Assessment System for Built Environment Efficiency
EAc	Category Credits Energy And Atmosphere
EPA	Environmental Protection Agency
FSC	Forest Stewardship Council
HVAC	Heating, Ventilation, and Air-Conditioning
IAQ	Indoor Air Quality
IEA	International Energy Agency
IEQc	Category Credits Indoor environmental quality
LEED	Leadership in Energy & Environmental Design
MRc	Category Credits Materials and Resources
SC	Shading Coefficient
VOCs	Volatile Organic Compounds

1. INTRODUCTION

Today, the world is witnessing significant developments within the construction industry, which include structural systems, construction methods, building materials and technologies. However, recent research and scientific studies have proved that there are negative impacts on humans and their environment, because of the unconscious choices in building materials or the lack of standards in the material usage. Extracting large quantities of raw materials in order to be used in the manufacturing of construction materials has negative impacts on the natural resources, such as, decreasing forests supply, destructing soil fastness, water fineness and other ecological hazards in the long term. There are many impacts of buildings on the environment that include:

- Utilizing 1/3 of the world's resources
- Being responsible for 40% of world's global greenhouse gas emissions
- Using 12% of the world's water
- Providing poor indoor air quality by containing up to five times more pollutants than outdoor air
- Being responsible for 40% of solid waste generated globally (Brundtland, et.al., 1987).

Nowadays, the excessive discharge of the greenhouse gases, like nitrous oxide, carbon dioxide and methane cause environmental damage to the planet due to the global temperature rise. This phenomenon constitutes a serious threat to the planet, which is called Global Warming. Increasing the concentration of these gases in the atmosphere cause an increase in global temperatures, which has catastrophic effects on the climate, sea levels, biodiversity and human health.

Therefore, designers should choose environmentally friendly materials in order to lessen the impact of global warming, create healthy environments for people and lower the negative effects to ensure the global sustainability. Building materials sometimes come from natural resources such as earth and forests, or they may come from an industrial operation and recycling. Whether they come from natural resources, industrial processes, or recycled materials, environmentally friendly materials are needed to make buildings and cities sustainable.

1.1. Aim and Scope

The main aim of this thesis is to develop a classification system for the usage of eco-friendly materials in Interior Architecture, in order to achieve a higher level of sustainability in the construction industry.

The study also includes developed guidelines derived from the analysis of LEED Green Building Rating System and various studies in literature, regarding choosing eco-friendly materials. The criteria set out and the developed classification system for materials, will be benefitted for maintaining a clean and healthy environment. By the use of these guidelines, excessive consumption of natural resources, as well as possible harmful emissions will be reduced. The scope of the study covers only the assessment of the materials to be used in interior architecture.

1.2. Methodology

Research methodology includes research on fundamental terms and concepts of sustainable design, as well as the evaluation criteria for eco-friendly materials. Furthermore, a classification system for eco-friendly materials to be used in interior architecture is established, and based on the analysis of LEED Green Building Rating System; criteria for the selection of eco-friendly materials in sustainable interior design are identified.

1.3. Structure of the Thesis

The thesis consists of six chapters. In the first chapter, the importance of sustainable design, that become a fundamental issue in Interior Architecture; and the aim, scope and methodology of the thesis are stated. The second chapter delivers the background study on the issue of sustainable architecture by defining the basic terms and concepts. Moreover, the sustainable design parameters are examined in general. The third chapter focuses on the factors to consider for green material choices, which can be summarized as; embodied energy of materials, contribution in energy efficiency of buildings, global resource limitations, rapidly renewable materials, local availability of materials, as well as durability and toxicity. In the fourth chapter, mostly used green building assessment tools, namely LEED and BREEAM are analyzed, and a comparison of them regarding their material categories is provided. The fifth chapter consists of the analysis of the criteria for the selection of eco-friendly materials in Interior Architecture, and an established classification system for the green materials to be used in interior spaces, under the sections; floors, walls, ceilings, insulation, windows, furniture and fabrics. Moreover, the criteria for the selection of eco-friendly materials in sustainable design are developed and a summary of the developed classification system and criteria list is given. Finally, the last chapter presents the conclusion of the study.

2. SUSTAINABLE ARCHITECTURE

Over the recent years, it is possible to see many changes that have happened in engineering fields and the construction industry, for the development of buildings that are environment responsible. Sustainable buildings have a sensitive approach towards materials, water, land, and energy that are much more efficiently used than traditionally constructed buildings. These sustainable or green buildings have less damage on the environment.

Green buildings can be identified by the lack of production of the greenhouse gases that cause global warming and environmental pollution. This pollution is created by heating up of the gases that exist in the atmosphere and characterized by their ability to absorb infrared radiation, and therefore causing global warming (Greenhouse gas, n.d.).

Moreover, the interior spaces of green buildings are healthy, comfortable and productive environments. Thus, the movement towards sustainable design is very important in order to eliminate the environmental impact of traditional buildings.

2.1. Definition of 'Green' and 'Sustainable'

Although the terms 'Sustainable' and 'Green' are often used interchangeably; they are different concepts. Sustainable design, which is a broader concept, covers three dimensions, which are environmental, economic, and social factors; whereas green design is related to environmental factors only (Tudora, 2011).

2.2. Sustainable Development

Today, the concept of sustainable development is found in many industries and disciplines. However, the initial and basic definition of the term was first introduced in the report; Our Common Future; by Gro Harlem Brundtland in 1987, as:

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland,et al., 1987, p.41).

Sustainable development depends on two main concepts: first concept is fulfilling fundamental needs, especially taking into consideration the needs of the world's poor. The second concept is the idea of having full control of the technology and understanding the surrounding environment regarding social factors. Sustainable design is based on the ability of fulfilling future needs, considering the following principles:

- Reduction of the consumption of non –renewable resources
- Preserving the natural environment
- Eliminating harmful emissions

2.3. Parameters of Sustainable Design

Today; designer, architect, builder and building owner are more interested in green and sustainable buildings. The concept of sustainable construction counts on a variety of strategies, including usage of green building materials in the design and implementation of projects. Sustainable buildings display a variety of benefits including:

- Lower maintenance needs
- Reduced energy consumption
- Increased occupant health conditions and productivity
- Lower costs for spatial alterations
- Higher levels of design flexibility

- Reduced environmental pollution

Sustainable buildings must follow a clear and eco-friendly approach for every part of the plan; starting from the site to choose for the construction. It is a well –known fact that buildings have a large impact on the environment throughout their stages of construction, and operation, namely by consuming substantial quantities of energy, water and materials, as well as by creating great amounts of waste.

Sustainable design covers the following principles:

•Reducing the consumption of non-renewable resources

•Improve the natural environment

•Avoiding the use of toxic substances

Life Cycle Assessment (LCA) is a method which is used to evaluate the potential environmental impacts that are associated with a service, building, or product by collecting related inputs and outputs. Finally the inventory results are interpreted for evaluation (Vatalis et al., 2013).

LCA is also known as the analysis from cradle to the grave of a product, starting from extracting raw materials, to manufacturing, distributing, using and disposing or recycling. Designers are using these techniques in order to assess the life cycle impacts of buildings or products.

The stages considering the environmental impacts related to the life cycle of any artifact, from manufacturing until the end stage of use can be seen in Fig2.1.

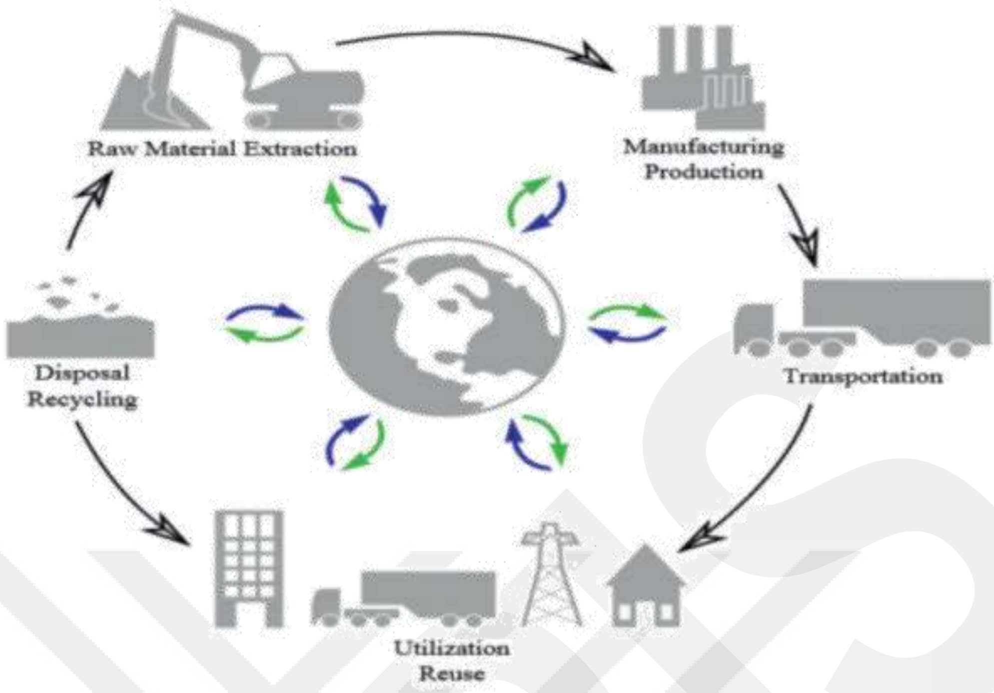

Fig 2.1. Scheme of LCA (Vatalis et al, 2013, p.749)

When making decisions for sustainable buildings, it is important to consider what is working best for a project and offer better options for efficiency. Before any decision, it is wise to make a thorough research and evaluate several available choices.

Within the design and construction process, it is seen that, approaching towards the end of the process, implementation of sustainable building technologies becomes harder and costly.

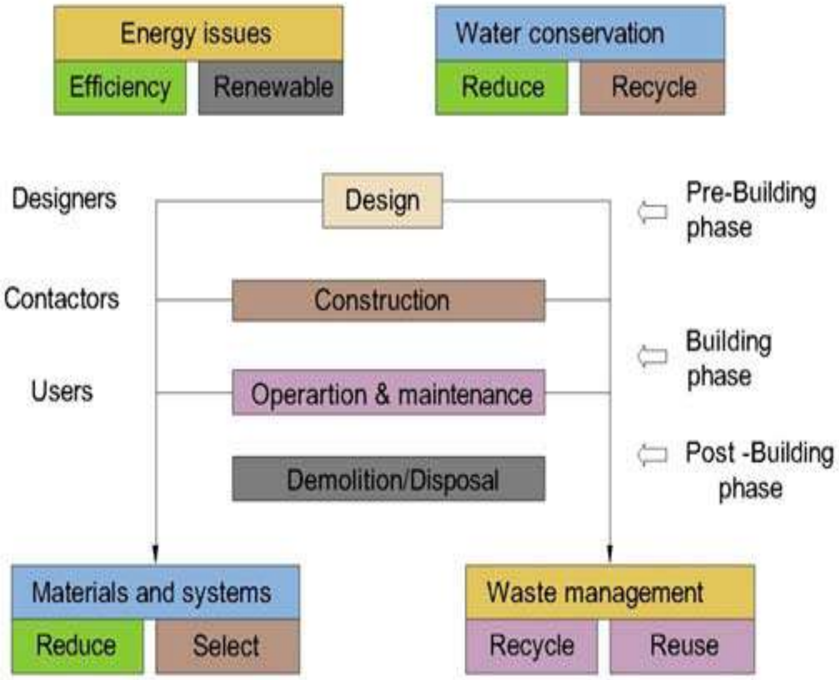

Fig 2.2. Sustainable construction principles (Tudora, 2011, p.130)

The figure 2.2 above illustrates the sustainable construction principles that are; energy issues, efficient and renewable resource consumption, conservation of water, efficiency of materials and systems, and waste management. In addition, the principles of sustainable architecture depend on the choices of designers and users, regarding eco-friendly materials, and methods of energy and water consumption.

2.3.1. Energy Efficiency and Renewable Energy

Buildings have a significant impact on the environment and the amount of energy use. “Commercial and residential buildings use almost 40% of the primary energy and approximately 70% of the electricity in the United States. The energy used by the building sector continues to increase, primarily because new buildings are constructed faster than old ones are retired. Electricity consumption in the commercial building sector doubled between 1980 and 2000, and is expected to increase another 50% by 2025 “(Vatalis,et al., 2013, p.750).

Designers should pay particular attention to the energy issue by applying energy efficiency strategies, such as high-performance lighting, HVAC systems, insulation, building envelope improvements and commissioning (Freeman, 2015). Energy efficiency strategies, such as solar and wind energy, can increase energy savings when combined with green building financing techniques. Each of the aforementioned strategies can reduce a buildings' greenhouse gas emissions.

As observed by David Hartley, renewable energy technologies manufacture marketable energy by changing natural phenomena into helpful energy forms. These technologies use the inherent energy in daylight, and its direct and indirect impacts on the planet (photons, wind, falling water, heating effects, and plant growth), gravitational forces (the tides), and the heat of the Earth's core (geothermal) (Hartley, 1990). Energy-efficient buildings use less energy, and therefore provide improved comfort as well as, economic savings for residents of houses and owners of businesses (Kim and Rigdon, 1998).

System Efficiency: Heating, ventilation, and air-conditioning (HVAC) systems should be chosen regarding the systems to adjust the thermal conditions, which would result in greater efficiency. Therefore, it is important to pay attention to several factors such as peak time temperatures. Regular maintenance programs are also necessary to keep operations at peak potency.

2.3.2. Water Efficiency

Based on the global organization of Environmental Program, buildings drain 20 % of the world's available water (Levin, 1991). Buildings use water at the interior and exterior. Green buildings are able to achieve up to 40% water savings compared to traditional buildings by incorporating indoor and outdoor water conservation technologies and strategies. These strategies for achieving water efficiency are:

- Water Efficient Appliances, Fixtures, and Toilets
- Gray Water Recycling Systems
- Water Efficient Landscaping
- Smart Irrigation Systems (Levin, 1991).

The fundamental factor for increasing water efficiency in residences is to decrease the utilization of water for non-consuming functions. There are two ways to achieve this: collecting fresh water and recycling indoor waste water. The first parameter can be managed by installing cisterns, which are able to collect and store runoff water from rooftops or different surfaces. Furthermore, waste water generated by laundry machines, dishwashers, bathtubs, and sinks, which is called as gray water, not containing any human waste, waste matter or sewage, can be used by recycling(Freeman, 2015).

According to the EPA, in America more than 50% of publicly supplied water is being used at houses (EPA Home, 2016). "Of this consumption, a 1999 study by the American Water Works Research Foundation found that 26.7 %of water is used for toilet flushing, 21.7% is used for clothes washers, 6.8 % is used for showering, 15.7% is used by faucets, 14% is wasted due to leaks and 5.3 % are from other unknown sources" (Vatalis, et al., 2013, p.750).

Reducing water consumption and the use of excessive water is for the protection of water resources. It is one of the most fundamental goals in the construction process. The possibility of reducing water consumption must rely on techniques and methods to collect, purify and re-use water. This can be applied by recycling and using waste water in toilet flushing or irrigation (Freeman, 2015).

Waste water is additionally reduced by utilizing water-preserving fixtures such as ultra-low flush toilets and low-flow showerheads. The primary goal of the water treatment process is that it is used to reduce the amount of water inside the houses and increase the amount of gray water to be used in the irrigation of green areas. Therefore, reducing the demand for fresh water and reducing costs (Freeman, 2015).

It is possible to reduce the use of water for irrigation, by planting resistant species which need small amounts of water. In order to use less water in the outdoor environments, it is possible to plant high density trees.

These plants require different and efficient irrigation techniques in order to reduce the consumption of water. Drip irrigation can be used in order to deliver the water into the root of plants and reduce water consumption due to evaporation.

Landscapes are consuming water excessively. As modern technology to monitor or use water is mostly installed, a water effective irrigation system, reusing graywater or rainwater for irrigation can cut outdoor water usage for landscaping.

Drip irrigation systems save water by irrigating, aerating trees and fertilizing plants, shrubs and bushes directly at the roots. When the traditional irrigation system is compared to drip irrigation, it is seen that the drip irrigation can save up to 20-70% of water, compared to traditional irrigation systems. Moreover, drip irrigation can provide deeper root systems which prevent erosion and lead to more effective fertilization (Freeman, 2015).

2.3.3. Indoor Air Quality

Providing the well-being of building occupants is a fundamental factor of green buildings. Buildings that have the ability to reach to views and daylight, utilize low emitting materials, deliver ample natural or mechanical ventilation, actively monitor indoor air, and operate efficient HVAC systems are created to achieve better indoor environmental quality (Levin, 1991).

A considerable rate of buildings has important air pollution sources as well as inadequate ventilation. The mechanical ventilation systems mostly are not designed and operated to outfit adequate quantities of outdoor air. There has been a rise in the incidents of reportable health issues (Levin, 1991).

Many typical problematic VOC compounds discharged from building materials include formaldehyde, acetaldehyde, toluene, isocyanates, xylene, and benzene. VOCs are usually emitted at high levels in the beginning and reduced to lower levels over time. By many researchers ventilation is viewed as a vital method for the IAQ management. The main ventilation considerations for the IAQ control (Levin, 1991) are:

- Dilution by outdoor air ventilation
- Air intake locations
- Building exhausts locations
- Air cleaning and filtration
- Space air distribution
- Heat recovery
- Microbial control

The issue of indoor air quality, considering a variety of building types; whether residential, commercial, office, or institutional buildings, is a unique public health and policy issue. The pollution of building surfaces by hazardous substances such as lead, and pesticides relate to IAQ concerns that are limited to industrial indoor environments.

" Indoor environmental problems, as they are experienced in residential and non-residential structures, tend to have their own unique aspects. In non-residential buildings, occupants have little or no control over their environments, which are owned and managed by others. In theory, homeowners and lessees have some degree of freedom to modify (for better or worse) the environments in which they live" (Godish, 2016, P.4).

Due to the nature of activities and the method of building construction and maintenance, residential and non-residential buildings usually have a significant difference in the nature of IAQ problems and associated health risks. The method of the problem investigation also differs in these types of buildings (Graedel and Allenby, 1995).

In addition, exposure to substances such as lead, asbestos, and formaldehyde that have high VOC emissions in a building cause health problems, owing to poor indoor-air quality. This is known as the Sick Building Syndrome. Such issues related to green buildings have become fundamental concepts in sustainable architecture today.

2.3.4. Material Resources

Buildings today are responsible for the usage of a very large amount of raw materials globally. As found in the study of Tudora (2011, p.130), “Building and construction activities worldwide consume 3 billion tons of raw materials, each year, or 40% of total global use”.

Moreover, according to the World Watch Institute (Roodman, Lenssen, & Peterson, 1995, p.11) “40% of our raw materials used are from buildings. Buildings are thought to be responsible for as much as 30% of our total waste output. As such, the development of healthy buildings needs us to make several selections in terms of sourcing, reusing, reducing, recycling and managing the materials we tend to use for construction and also the construction waste that's created as a result”.

Using green building materials in projects helps to minimize the environmental impacts related to the extraction, fabrication, transportation and installation processes.

On the other hand, building and material reuse can help to protect the sustainability process. Annually, about 170,000 new commercial buildings are constructed, and about 44,000 commercial buildings are deconstructed. Reusing parts of previously constructed buildings will facilitate to preserve and conserve resources, reduce waste and reduce the environmental impacts of new buildings, by reusing exterior parts like walls, roofs, and floors or interior elements. Green buildings will divert the 170 million tons of waste materials that head to landfills because of construction, renovation, and demolition. Such materials used; i.e. salvaged, refurbished, or reused materials may help cut back the demand for virgin materials and reduce waste (Kim and Rigdon, 1998).

The Environmental Protection Agency (EPA) recommends reusing materials from demolition building sites (Rezaallah, Bolognesi and Afsheni, 2012). It is common to confuse reused and recycled materials. Reused and salvaged material is a waste that is saved and used once more in its original function, whereas recycled material is waste that has become a brand new product (Kim and Rigdon, 1998).

Life cycle analysis of building materials is substantial in order to enable a comparative analysis of sustainable applications. Besides the local economic advantages of the use of locally excavated and manufactured construction materials, less total embodied energy, and consequently less overall energy is needed for the transportation of materials. In other words, the main purpose of choosing local materials is to enhance the national economy as well as reducing the overall energy needed for the transportation of materials to the project site (Hussein, 2012).

Building materials are preferred to be manufactured off site and then transported to the site where possible, in order to maximize recycling and minimize waste, as well as to achieve better Occupational Health and Safety management, high quality elements, less noise and dust (Rezaallah et al., 2012).

On the other hand, the life cycle of a building material consists of three phases :

- Pre-building phase is the phase of manufacture; which covers extraction, processing, packaging and shipping.
- Building phase is the phase of use; which includes construction, installation, operation and maintenance.
- Post-building phase is the phase that depends on the method of waste management; which are either reusing or recycling materials (Fig 2.3.).

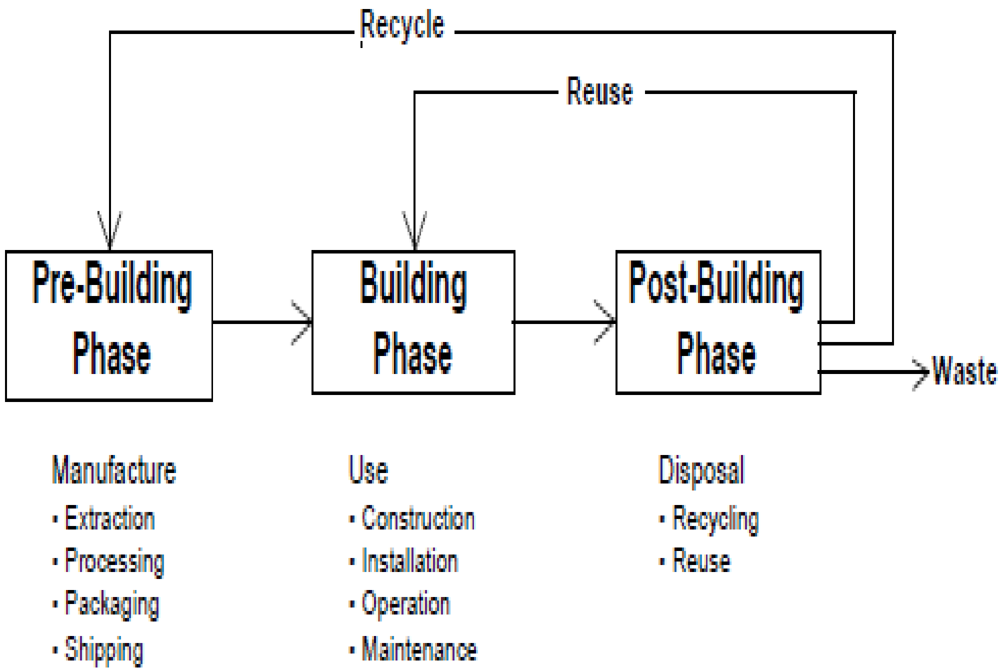

Fig 2.3. Three Phases of the Building Material Life Cycle (Kim and Rigdon, 1998, p.8).

Green building materials are regarded as renewable, recycled, reused and non-toxic materials. Certified wood from a third -party forest standard, rapidly renewable plant materials such as bamboo and straw, recycled stone and metal are some examples of environment friendly material alternatives. Others can be given as; sheep wool, panels made from paper flakes, compressed earth block, adobe, baked earth, clay, flax linen, rammed earth, vermiculite, sisal, sea grass, cork, expanded clay, wood fiber plates, calcium sandstone, concrete (high and ultra-high performance, roman self-healing concrete) (Hussein, 2012).

2.3.5. Waste Reduction

In many countries, the management of construction and demolition waste has become a major environmental problem. Sustainable architecture also aims to reduce waste materials that are produced during the construction process besides water and energy consumption. For instance, one of the main goals is reducing the waste materials that go to landfills. Buildings are often demolished when they reach the end of their useful life, and then hauled to landfills. However, many waste materials can be recycled and reclaimed into useful material, which is known as 'deconstruction'. Waste reduction may also be achieved by extending the useful life of a building.

Structure waste and finishing waste are the two main types of building construction waste. Throughout the construction process, components like reinforcement bars, concrete fragment, abandoned timber plates and pieces are generated as construction waste, while finishing waste is produced during the finishing phase of a building. As to careless use, broken raw materials like ceramics, mosaic tiles, paints and plastering materials become construction waste (Bossink and Brouwers, 1996).

About 1-10% by weight of the construction materials are estimated to leave the project site as waste. A comprehensive study was carried out on 86 residential projects in the Gaza strip. It was found out that approximately 3.6-11% of material loss is caused by direct and indirect wastes, significantly exceeding the value that were normally allowed, which is 2 - 4.5% (Vatalis et al., 2013).

Construction waste reduction during installation not only decreases the requirement for landfill spaces, but also achieves a cost saving. For example traditionally, concrete has been pre-mixed with water and then transferred to the project site. As a result, new shipments of excess material are often needed to prevent pouring delays. These excess materials are usually disposed of in a landfill or on site. Conversely, mixing concrete on site as needed reduces waste, and provides better quality control. There is also the possibility to reduce waste by designing floor intervals in accordance with the standard lengths of timber or steel framing members.

The waste reduction factor shows that the manufacturer ought to reduce the amount of scrap material which is produced, in order to make the production process more efficient. These material remains may result from various trimming, molding, finishing processes, as well as from damaged or defective products. Scrap materials can be integrated into the product or removed for recycling. In addition, waste products that are generated on site can be used in some industries to power their operations. Consequently, these choices decrease the waste that goes into landfills (Kim and Rigdon, 1998).

Most of the construction materials come in standard sizes. The waste material generated through the installation process can be significantly reduced by designing a building with standard sizes. Using materials efficiently is an essential principle of sustainability. Overall waste coming from trimming and fitting can be reduced with the use of common tools for materials that are easily installed (Kim and Rigdon, 1998). Moreover, light building materials such as wood is easy to work with and therefore, make renovations easier and minimize finishing waste.

In addition, well designed buildings also assist to decrease the amount of generated waste by the residents. This can easily be achieved by the availability of on-site solutions like compost bins to minimize substances going to landfills.

Construction waste management is important in the production of sustainable buildings as to handling the large amounts of waste that buildings create. Construction waste management efforts specializes in three methods of improvement :

i. Diverting construction waste from landfills and combustion facilities through recycling or selling.

ii. Re-using materials appropriately on-site.

iii. Redirecting recyclable materials back to manufacturing processes.

The waste materials which are generated during construction, can be recycled, reused in other projects, or given to nonprofit organizations as charities. All of these options guarantee that the whole life cycle of the building will be more sustainable.

3. EVALUATION CRITERIA FOR GREEN MATERIALS

As mentioned in Chapter 2, there are many reasons that increase the need for green materials and products, as well as the awareness and sensitivity towards the limited natural resources. In addition, because of the growth in the construction industry, the excessive use of natural resources which lead to irreversible environmental impacts has greater pressure on resources such as, natural stones, metal ores and forests. There are many parameters for choosing eco-friendly materials for green buildings. The following issues can be taken into consideration for the evaluation of green materials to be used in buildings, and the criteria list given at the end of Chapter 5 can be beneficial for the selection of them.

3.1. Embodied Energy of Materials

The embodied energy is the amount of energy that is needed to manufacture any building material. This includes the energy needed to extract the raw materials from nature, their transportation, the processing of raw materials, the energy required to manufacture the product, as well as the energy employed in distribution activities to supply a finished product. Every building is a complicated combination of many processed materials. Each of them contributes to the building's total embodied energy.

Embodied energy shows the environmental impact of building materials or systems. Figure 3.1 shows the embodied energy of some of the types of building materials in Gj, like Cement: 220, Plastic: 135, Steel: 140, Ceramics: 75, Glass: 50 and Wood: 35 (Tudora, 2011).

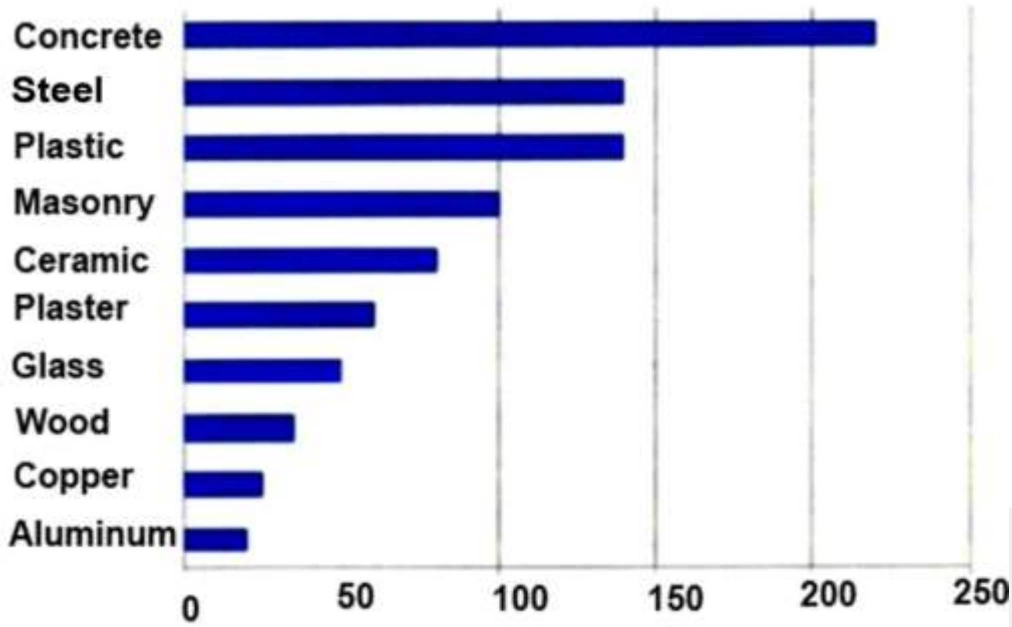

Fig 3.1. Embodied energy of some building materials in Gj (Tudora, 2011, p.132)

Fossil fuels, which are a non-renewable source of energy, are mainly used to power the equipment utilized for mining or gathering, the production devices, as well as the transportation vehicles that transfer raw materials to a processing facility.

By burning fossil fuels, the environment is affected negatively as they release nitrogen oxide into the atmosphere which then crates smog and acid rain. This process of burning fossil fuels is associated with transportation and industry. In order to reduce the Carbon Footprint in producing and transporting processes, it is important to consider materials with low-embodied energy values (Tudora, 2011). For instance, the production process of wood harvested in a sustainable manner, involves less energy and has a lower impact on the environment, compared to the production process of iron, which involves the use of more energy, as it has to be extracted from well-mined ores. In other words, conventional materials with high-embodied energy can be replaced with materials having low-embodied energy. In the Table 1 can be seen comparing embodied energy content of common building materials.

Table1. *Comparing Embodied Energy Content of common building materials* (Graham, 1984)

Material	Virgin	Recycled
Aluminum	196	27
Polyethylene	98	56
PVC	65	29
Steel	40	18

3.2. Contribution in Energy Efficiency of Buildings

The aim of using materials providing energy efficiency is that, lower quantities of energy will be needed during the operation / use phase of a building. This matter heavily depends on materials providing lower long-term energy costs by using concepts like R-value, shading degree and luminous efficiency. The materials that slow down the transfer of heat out of a building's layer decrease the energy needed for heating or cooling.

Material characteristics are mostly estimated through their insulating value. R-Value measures the thermal resistance in the building. Materials that have higher R-values are better insulators than materials with lower R-values. The R-value of materials depends on the resistance to heat conduction and thickness. R-values may be measured for individual materials such as insulation, siding, wood paneling or brick, and also studied for composite structural elements such as ceiling, wall, floor and window (Kim and Rigdon, 1998). Many kinds of insulation materials can be obtained from organic cellulose made from recycled paper, to petrochemical-derived materials.

Shading Coefficient: Although daylighting is a free, energy saving and eco-friendly type of illumination, the obtained heat gain from direct radiation is not preferred in very warm climates. Shading constant is a quantitative relation of the solar heat gain from the fenestration and the sheet of double-strength glass with a constant space. It gives a comparison of the sun-blocking efficiency of varied glass kinds, shading devices, and glazing patterns. Shading devices are designed to reduce solar heat gain. Overhangs permanently block high summer sun, while allowing light radiation throughout the winter. Some types of glazings or applied films give the ability of selective transmission of radiation (light), whereas preventing or reducing the transmission of infrared radiation, which is heat (Kim and Rigdon, 1998).

3.3. Global Resource Limitations

The construction industry is a significant consumer of raw materials in the global scale. The usage of each material has impacts on resources and increases environmental pollution, especially throughout its production process. This pollution can be avoided by reducing, reusing and recycling products instead of producing them from raw materials. These approaches will help to preserve natural resources and to lessen the energy use together with minimizing CO_2 emissions.

3.3.1. Reducing

Reduction in the use of materials will result in the decrease of potential energy to produce these materials, and the consumption of natural resources for the extraction of them.

Another way to reduce the consumption of resources is achieved by using fewer materials, to produce materials. ‘Dematerialization’ strategy is used to get maximum performance by using minimum materials. To reduce the material usage, the reduction of the volume of used resources is needed. The reduction of using materials, will reduce the generation of waste in the society for each unit of industrial product (McHenry, 1984).

The produced materials with less waste generation refers to that the manufacturer has used an efficient process in the producing operation, by reducing the amount of resource materials. These resources come from different trimming, finishing processes and moldings, or from damaged products. Products with these characteristics include reused, scrap, or recycled materials (McHenry, 1984).

3.3.2. Reusing

The intent is to promote the use of building materials through rescued, salvaged or reused material resources. By reusing materials, the extraction of raw materials from nature and waste materials going to landfills can be minimized, besides economic savings.

Recently, the reuse and recycling of materials are drawing more attention. By examining the waste management hierarchy and life cycle analysis of materials, the reuse and recycle opportunities of materials become a priority, considering the 'zero waste – reincarnation' concept (Hussein, 2012).

When a building has come to the end of its service life, its structural components and materials can be reused again and recycled. By this way, minimum of energy will be consumed, minimum of materials will be extracted for manufacturing and minimum of waste will be produced by the building. Many sustainable designs incorporate the use of reused materials, like reclaimed wood, windows, doors and bricks.

The historical preservation approach involves salvaging components of buildings that are in the phase of demolition.

It is possible to assemble building materials from the area surrounding the site. For instance, if a replacement structure is being created in a forest, wood from the trees that were moved from the building could be re-used as a part of the building.

Sustainable design incorporates the utilization of recycled or second-hand materials.

The application of reusing materials embraces economic, social and environmental factors.

Using Rescued, Salvaged and Refurbished Materials: Reclaimed and also salvaged materials are incorporated into new construction, thereby extending the lifespan of materials that would otherwise be discarded. Furthermore, transportation of these materials to landfills are avoided (Hussein, 2012).

Purchasing Reclaimed or Salvaged Materials: The following table shows the maximum transportation distances of some reclaimed materials. For example, the material with the highest distance is reclaimed steel with 4023 km. After that comes reclaimed timber with 1609 km. The last material is reclaimed tiles with 161 km (Husein, 2012). If the material to be transported is farther away from the project site than these given maximum distances, to purchase the product from that location would not be a very sustainable choice regarding the carbon emissions involved in the process.

Table 2. *Maximum Transportation Distances for Reclaimed Materials* (Hussein, 2012).

Material	Distance (KM)
Reclaimed tile	161
Reclaimed bricks	402
Reclaimed slate	483
Reclaimed timber	1609
Reclaimed steel	4023

3.3.3. Recycling

Recycling refers to the reprocessing of previously used products into new materials. Recyclable materials are usually collected from general waste or from construction sites. Building materials may come from recycled materials or waste materials. Recycled materials have a positive impact on the environment and the economy, which can be re-processed to be used in a different product. Major benefits of reusing and recycling materials are; energy saving, cost reduction, reducing the need for extracting raw materials, creating clean air and less waste, as well as reducing Green House Gases.

The following table 3 shows the environmental effects of recycling for several building materials. For example, the most beneficial material among the given materials is Aluminum with an energy saving of 95%. After that comes plastic with 70%, then comes steel with 60%, and paper with 40%. The last materials are glass and cardboard with 5-30% (Tudora, 2011).

Table 3. *Environmental Effects of Recycling Building Materials* (Tudora, 2011, p.133).

Material	Energy savings, [%]	Air pollution savings, [%]
Aluminum	95	95
Cardboard	24	-
Glass	5-30	20
Paper	40	73
Plastics	70	-
Steel	60	-

Considering the fact that each year twenty five billion tons of concrete is factory made globally, concrete is one of the most consumed materials. As it is a durable material, it does not become a waste as to its exhaustion, but the structure itself becomes redundant because of the need for infrastructural modifications (Hussein, 2012). An example can be given as the recycling of the remnants of concrete, made into products like mosaics or concrete tile. That is why the remnants of concrete are mostly recycled into products like mosaics or concrete tile.

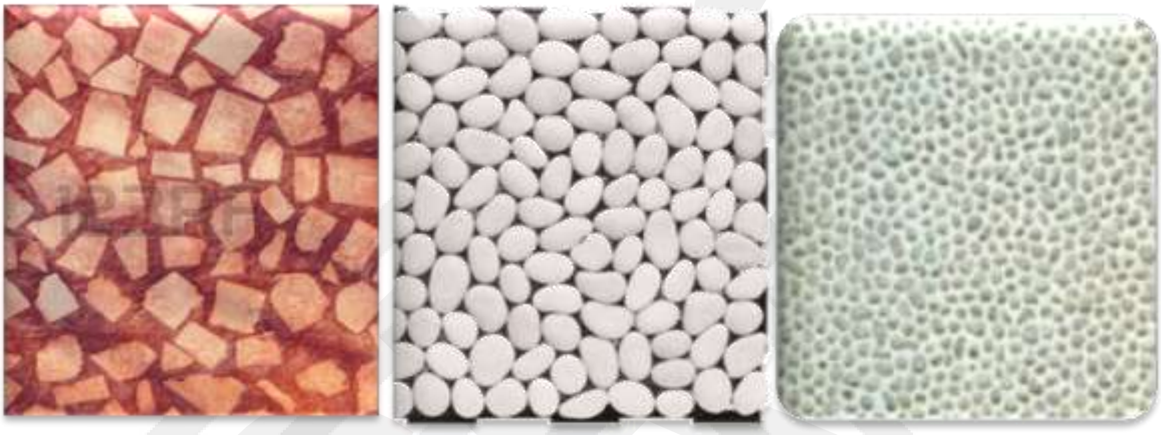

Fig 3.2. Recycled Materials (Mosaics, Stone and Concrete Tile) (Hussein, 2012).

Materials that contain other components in their structure are harder to recycle and separate from each other. This process of separating each component is less preferable in environmental terms, compared to the direct reuse of it. In order to recycle a material's content it must first be separated into recyclable components. The removal of structural steel from a building frame might be an easy process of disassembling, compared to more complex material contents; such as the attempts to separate metals, glass and plastics from a window or cladding panel made from composite materials.

The figure below shows the recycling of waste glass. For instance, waste glass is collected from construction sites and recycled as Glass Floor Tiles or Mosaic Ceramic.

Fig 3.3. Recycled Materials (Glass Floor Tiles or Mosaic Ceramic) (Hussein, 2012).

Recyclability is mostly measured as the material's capability to be used as a resource to make new products. Steel, which is typically the most recycled building material, is simply detached from construction scrap through magnets.

When materials cannot be reused as they are, they can be separated into recyclable components. Usually it is difficult to separate rubble from demolition sites. This process prevents materials from being recycled. Once separated, the materials are easy to recycle. For example, glass is easy to recycle and use in order to make window glass, ceramic tiles, and brick.

Plastics alone are simple for recycling; however, they are usually integrated into a different element that makes separation hard or not possible. Plastic laminates are typically adhered to ply board or particle board, leading the wood product to be recycled even more difficultly (Hussein, 2012).

Storage and Collection of Recyclables

The average person produces 1.82 kg of trash each day. In 2009, Americans produced enough trash to circle the Earth twenty-four times. Over 75% of waste is recyclable, however; there is a tendency to only recycle about 30% of it. As a prerequisite, LEED certified buildings need to minimize waste that goes into landfills; through recycling metal, glass, paper, plastic, and cardboard (Kim and Rigdon, 1998).

Using Materials with Recycled Content

Some of the examples of materials that have a recycled content can be given as concrete, steel and furniture. There are two types of materials regarding their recycled content:

1. Pre - Consumer Recycled Content

2. Post - Consumer Recycled Content

Pre-consumer recycled content is the material that is transferred through the waste stream during the production method. It is the manufacturing waste, which does not reach the consumer. Some examples include shavings, sawdust, walnut shells, fly ash, over issue publications and texture clippings.

Post-consumer recycled content is referred to as consumer waste and it is generated through households or industrial and institutional facilities, by the end-users of the merchandise. This waste material will not be used for its supposed purpose (Kim and Rigdon, 1998). Several alternative examples contain newspapers, construction, and demolition rubbish, glass and plastic bottles, cans and also steel.

3.4. Rapidly Renewable Materials

The goal here is to promote the use of quickly renewable building materials, which are materials produced from agricultural products that takes less than 10 years to grow and harvest. Materials such as; Bamboo Flooring, Cotton Batt Insulation, Wool Carpeting, Linoleum Flooring, Sunflower Seed Board Panels, Wheat Board Cabinetry and Cork Flooring can be given as examples (Hussein, 2012).

3.5. Local Availability of Materials

Locally available materials should reduce the energy consumed for the transportation of materials, and the harmful greenhouse gas emissions that lead to environmental pollution and global warming.

One measure of a product’s eco-friendliness should be the distance that the product has traveled from extraction to application at the project site. More the distance traveled, more the energy used and greenhouse gases emitted. LEED aims to encourage the use of materials that are not only extracted, harvested, and recovered, but conjointly are factory-made 800 km away from the project site (Freeman, 2015).

The goal here is to encourage the use of locally available materials and contribute to the recovery of local economy, and minimize the negative effects resulting from the transferring process. It should be remembered that the cause of global temperature rise is a result of the continuous GHG emissions.

Transportation of materials is a significant factor regarding energy consumption, especially for massive materials such as masonry, concrete and steel. Marine shipping has the lowest energy consumption in terms of energy units/mass units/ distance units (mj/kg/km), followed by rail shipping and trucking. The highest energy consumption, pollution caused and costs are seen in air flights (Berge, 2009).

Table 4. *Energy Consumption in Transportation of Materials* (Berge, 2009).

Transport mode	MJ/t/km	Co2 k/km
By air	33…36	-
By road (diesel)	0.8…2.2	0.069
By rail (diesel)	0.6…0.9	0.060
By rail (electric)	0.2…0.4	0.065
By sea	0.3…0.9	0.115

Using local materials shortens transportation distances and reduces air pollution created by vehicles. Local materials are often suitable to climatic conditions of the project site. In order to reduce costs and carbon footprint, local materials should be used, but in case of unavailability it is important to consider the packaging and the amount of materials. Therefore, materials that are located at far distances from sites are not wise options and should be replaced with more sustainable alternatives (Roussesa, 2009).

3.6. Durability

There are many considerations related to the durability of building materials and systems; that depend on the type of building, method of design, method of installation, implementation, as well as maintenance. Therefore, it is very difficult to evaluate the extent of durability (Tudora, 2011). However, some considerations are given below:

- Disposal frequency – the anticipated time period of a system or product before it should be removed and replaced – the estimated time is based on the period of guarantee, given by the manufacturer.
- Durability is based on maintenance – some products that have a long life span, if not maintained properly, can have a shorter life span.

- Durability is based on interdependence of systems – depends on the relationship between the assorted parts of a system, to create the complete system and perform as designed.

Selecting durable materials; besides price savings for the building owner or investor, additionally reduces waste going to landfills, and reduces the raw materials and energy consumption needed for the production of materials. This, as a result, leads to the sustainability of the building for a longer period of time, also less cost (Tudora, 2011).

3.7. Toxicity

To achieve a healthy environment free of contaminants and an improved indoor air quality, environment friendly and non-toxic materials should be selected. Non-toxic materials are safer for the occupants of the buildings and the surrounding environment, as well as our planet. Toxic emissions have negative effects on air quality in enclosed spaces and to public health. For example, glues emit dangerous gases and fumes that spread in the air. Once installed; these will contribute to air quality issues throughout a building's lifecycle.

An increase in the use of petroleum based materials and air tight buildings created today's health problem, which is called the "Sick Building Syndrome" (SBS). The SBS may occur because of insufficient natural or mechanical ventilation to get rid of odors and chemical substances that are emitted by building materials. The resins in ply board, particleboard, and also the chemicals utilized in foam insulation may lead to Sick Building Syndrome. Gas, benzene, ammonia, and different unsafe or cancer-causing chemicals are found in several building materials, furnishings, and clean up solutions (McHenry, 1984).

The greenhouse gas emissions and air pollution increase at indoors, as to the lack of fresh air entering the building. The air entering through gaps and cracks should be avoided since, a good insulation for thermal conditions or noise control is needed. In a long period of time, this increases the concentration of gases and increases the negative health effects.

By choosing materials with lower or nonexistent levels of harmful emissions, negative health issues are often avoided. Material toxicity is of accelerating concern with the growing range of building merchandise containing petroleum distillates (McHenry, 1984).

These harmful chemical emissions are called Volatile Organic Compounds (VOCs). The emissions of dangerous gases after the installation process is called 'outgassing'. Spreading of gases and chemical reactions are mostly found in glues, paints, and insulation materials. These toxic emissions could spread in the air for a short period and sometimes completely disappear with the passage of time (McHenry, 1984).

Not only these mentioned materials, but also many other building materials emit air pollutants. There are three main types of indoor air pollutants: 1. Carcinogens, 2. Irritants, and 3. Odors (Vatalis et al., 2013).

VOCs vaporize at room temperatures. They are comparatively inert in normal concentrations; however, they will be mixed within oxidants like oxide and nitrogen dioxide to make reactive species and probable irritants, varied acids and also aldehydes. Volatile Organic Compounds might cause eye and higher metabolism irritation, nasal congestion, headache, as well as vertigo. Samples of materials, which contain Volatile Organic Compounds are, but not limited to, solvents, paints, adhesives, carpeting, and particleboard.

Paints and stains should not include Volatile Organic Compounds in more than two hundred g/lt. Varnishes should not contain Volatile Organic Compounds in more than three hundred grams /liter. Low Volatile Organic Compound paints require no special instruments or application methods.

To improve indoor air quality, the following criteria should be considered:

- Low or Non-Toxic Materials: Materials without poisonous gases that cause diseases like cancer.

- Low VOC Assembly: Materials with least or non-Volatile VOC producing compounds.

- Moisture Resistance: Materials resistant to biological contaminants inside buildings, as well as resistant to moisture in the absence of good ventilation.

- Healthfully Maintained Materials: Materials that do not need special care.

- Systems or Equipment: Products which promote healthy indoor environmental quality, protecting occupants from distinctive indoor air pollutants (Vatalis et al., 2013).

To sum up; according to the study of Suzer and Yılmaz (2010);

> Material choices can also be limited by toxicity concerns. The designer's objective is to select materials that have the least significant toxic properties. As to toxicity concerns, it is also advised that natural materials should be preferred over synthetic ones due to the potential harm they give to the natural habitat and human health. However, it should also be considered that consuming global resources vastly, for that sake of using natural materials also constitutes a great danger for next generations, as it would lead to the depletion of them. As a result, it can be said that the aim is to choose abundant, non-toxic, non-regulated materials, design for minimum use of materials and try to get the needed materials through recycling streams than through raw materials (Suzer and Yılmaz, 2010, p.834).

4. GREEN BUILDING ASSESSMENT TOOLS

In order to provide sustainable solutions for contemporary as well as possible future needs, and to preserve the ideal conditions on Earth, numerous assessment methods and systems are developed for sustainable architecture, worldwide.

Green building assessment tools are based on the objective assessment of resource use, environmental loads and indoor environmental quality. These tools provide various specific criteria for the development of green buildings. Some of the widely used environmental assessment tools include; BREEAM, developed in the United Kingdom, LEED, developed in the United States, and CASBEE, which is developed in Japan.

Furthermore, many countries have, or started to develop their own environmental assessment tools, as it is not possible to assess buildings regarding the local conditions they are in, from a global perspective (Suzer, 2015).

Some of the presently used building environmental assessment tools are given in Table 5.

Table 5. *Currently Used Environmental Assessment Tools* (Rezaallah et al., 2013).

	Country Of Origin	Green Building Assessment Tool (S)
1.	Australia	Nabers / Green Star
2.	Brazil	AQUA / LEED Brasil
3.	Canada	LEED Canada / Green Globes / Built Green Canada
4.	China	GBAS
5.	Finland	PromisE
6.	France	HQE
7.	Germany	DGNB / CEPHEUS
8.	Indonesia	Green Building Council Indonesia (GBCI) / Greenship
9.	Philippines	BERDE / Philippine Green Building Council
10.	South Africa	Green Star SA
11.	Switzerland	Minergie
12.	United States	LEED / Living Building Challenge / Green Globes / Build it Green / NAHB NGBS / International Green Construction Code (IGCC) / ENERGY STAR
13.	United Arab Emirates	Estidama
14.	Czech Republic	SBToolCZ
15.	Hong Kong	HKBEAM
16.	Korea	KGBC
17.	India	Indian Green Building Council (IGBC) / GRIHA
18.	Japan	CASBEE
19.	Mexico	LEED Mexico
20	New Zealand	Green Star NZ
21.	Portugal	Lider A
22.	Italy	Protocollo Itaca / Green Building Council Italia
23.	Singapore	Green Mark
24.	Spain	VERDE
25.	United Kingdom	BREEAM

Mostly these green building assessment tools rely on a set of standards, rules and specifications, created by these organizations. There may be some minimum requirements to be met by the buildings for specific environ mental issues. Furthermore, by trying to earn the largest number of points under certain categories, such as site selection and use, construction techniques, energy and water conservation, maintenance, as well as occupant comfort and health, the resulting credit scores help to identify the level of sustainability achieved by the building.

This section will examine the two mostly used green building assessment tools; LEED and BREEAM by focusing on their evaluation methods for building materials only.

4.1. LEED

Leadership in Energy and Environmental Design (LEED) certification program was founded by the US Green Building Council to create an evaluation tool to measure and compare the level of sustainability of buildings (USGBC, 2009).
Forty –two different environmental performance criteria set by LEED are divided under seven categories, which are:

- Energy and Atmosphere
- Water Efficiency
- Sustainable Sites
- Materials and Resources
- Indoor Environmental Quality
- Innovation & Design
- Regional Priority

LEED points are calculated through checklists that can serve designers and decision- makers as guidelines.
The total number of earned points helps to determine the certification level achieved by the building. LEED ratings possible to achieve are; Certified, Silver, Gold and Platinum (USGBC, 2009).

Table 6. *LEED Certification Levels*, (USGBC, 2009).

LEED Rating	Points
Certified	40-49
Silver	50-59
Gold	60-79
Platinum	≥ 80

4.2. BREEAM

Building Research Establishment Environmental Assessment Methodology (BREEAM), which is the first system to assess buildings as green or sustainable, was introduced into the market in 1990, by the Building Research Establishment Global Limited (BRE Global).

The system was originally designed as a national system for offices and residential buildings, however today, BREEAM certification is used for various types of buildings, including both existing and newly constructed buildings, applied worldwide (BREEAM, 2014). The 10 Environmental categories of BREEAM are:

- Energy
- Materials
- Innovation
- Waste
- Pollution
- Health & wellbeing
- Water
- Transport
- Management
- Land Use and Ecology

Buildings receive credits from the various issues set under these 10 categories. The gained scores for each category are then summed to determine the overall score of the building.

The level of sustainability is derived from this total (percentage) points. The six rating levels of BREEAM are as follows; Unclassified (0-30%), Pass (30%-44%), Good (45%-54%), Very Good (55%-69%), Excellent (70%-84%), Outstanding (85-100 %) (BREEAM, 2014).

Table 7. *BREEAM Certification Levels* (BREEAM, 2014).

BREEAM Rating	Overall Achievement
Unclassified	< 30%
Pass	≥30%
Good	≥45%
Very good	≥55%
Excellent	≥70%
Outstanding	≥85%

4.3. Comparison of LEED and BREEAM Regarding their Material Categories

The two widely used building assessment tools have many overlapping issues, as well as differing ones.

Table 8, given below, summarizes the level of similarity regarding their environmental concerns. As seen from the table, the category of Energy has the highest similarity percentage. The category of Materials also shares an equal percentage of 12.5%, in both of the systems (Elgendy, 2010).

Table 8. *Overlapping Categories and their Influences on LEED and BREEAM Tool, (Elgendy,2010).*

Category	LEED BD+Cv4	BREEAM UK 2015
Site Selection & Ecology	24.5%	20.5%
Water	5.5%	2.5%
Energy	33%	33%
Materials	**12.5%**	**12.5%**
Indoor Environment Quality	14%	13%
Innovation	6.5%	6.5%
Facility Management	-	12%
Regional Priority	4%	-

LEED

Materials and Resources (MR) category of LEED focuses on minimizing the embodied energy and different impacts related to the extraction, processing, transport, maintenance and disposal of building materials.

Sustainable architecture considers the life cycles of products and buildings and aims for improving resource efficiency (USGBC, 2016).

MR category found in LEED’s Building Design and Construction (BD+C) v. 4 scheme is composed of the following criteria:

- Storage and Assortment of Recyclables

Decreasing waste, which are produced by building occupants and sent to be disposed in landfills (USGBC, 2016).

- Construction and Demolition Waste Management

Decreasing construction and demolition waste to be disposed in landfills and combustion facilities, by reusing and recycling materials (USGBC, 2016).

- Building Life-Cycle Impact Reduction

Encouraging adaptive reuse projects to optimize the environmental performance of products and materials (USGBC, 2016).

- Building Product Revelation and Improvement - Environmental Material Declarations

To reward project teams for selecting products verified to have been extracted or sourced in a responsible manner (USGBC, 2016).

- Building Material Revelation and Optimization - Sourcing of Raw Materials

Encouraging the utilization of products and materials with obtainable life-cycle data and, preferable environmental, social and economic life-cycle impacts (USGBC, 2016).

- Building Product Revelation and Improvement - Material Ingredients

To reward design teams for selecting products, which their chemical compounds are inventoried in an acceptable method, and are verified to eliminate the use and generation of harmful substances (USGBC, 2016).

BREEAM

Materials category of BREEAM has the main objectives of reducing the impact of construction waste and lessening the environmental impact of materials (throughout the processes of extraction, manufacturing, recycling or reuse); by taking all of the phases into consideration (namely; design, maintenance and operation) and making sure that products or materials coming from responsible or known sources are used (BREEAM, 2014).

Materials category of BREEAM is composed of the following:

- Life Cycle Impacts

To recognize and support the use of construction materials with minimum environmental impact (including embodied energy) over the total life cycle of the building (BREEAM, 2014).

- Protection of Hard Landscaping and Boundary

To identify and encourage the use of materials for boundary protection and hard exterior surfaces that have minimum environmental impact, by taking the overall life cycle of used materials into account (BREEAM, 2014).

- Responsible Sourcing of Construction Product

To recognize and encourage the use of responsibly sourced materials for key building parts (BREEAM, 2014).

- Insulation

To encourage and support the use of thermal insulation materials, which provide a low environmental impact of the building, related to their thermal features (BREEAM, 2014).

- Material Efficiency

To recognize and encourage the efficiency of the used materials, as to minimizing the negative effects of buildings (BREEAM, 2014).

5. THE ANALYSIS OF CRITERIA FOR THE SELECTION OF ECO-FRIENDLY MATERIALS IN INTERIOR ARCHITECTURE

5.1. Classification of Materials used in Interior Architecture

A classification system according to the usage area of building materials in interior spaces would be beneficial for the selection of them for various applications. The classification of materials to be used in interior spaces is as follows:

5.1.1. Materials for Floors

- Wood: Coming from responsibly managed forests; which is certified by organizations such as the Forest Stewardship Council (FSC)
- Rapidly Renewable Materials: Such as; Bamboo, Cork and Rubber. Strong and moisture resistant materials which have very short periods of harvesting time, namely less than 10 years
- Natural Stone

Fig 5.1. Linoleum, Wool Carpeting and Cork Flooring (Husein, 2012, p.7).

5.1.2. Materials for Walls

- Paint: Using non-toxic components and low VOCs that do not contain toxic gases like formaldehyde, ammonia, etc. Paints that can improve the indoor air quality should be preferred in enclosed spaces (Hussein, 2012).
- Tiles: That have an industrial waste composition in the past, such as recycled tiles, ceramics, porcelain and glass
- Plaster: Natural clay plaster allows a wall to absorb and release moisture.
- Wallpapers: Made from rapidly renewable sources such as Plant Fibers, Cork, etc

5.1.3. Materials for Ceiling

- According to the criteria of Global Resource Limitations, Gypsum and Foam can be used.
- According to the criteria of Rapidly Renewable Materials; Cork, Bamboo, and Rubber can be used.

5.1.4. Materials for Insulation

- Using insulation materials such as Cotton Batt and Rockwool would have a positive effect on energy efficiency (Hussein, 2012).

Fig 5.2. Cotton Batt Insulation (Hussein, 2012, p.6).

5.1.5. Materials for Windows

Design decisions on window assemblies are important as they help to control the heat gained and lost inside the building.

- Low- E coating that increases the insulation level.
- Use of inert gases like Argon and Crypton.
- Wood made from FSC certified forests.

Fig 5.3. Certified wood, FSC (Hussein, 2012, p.7).

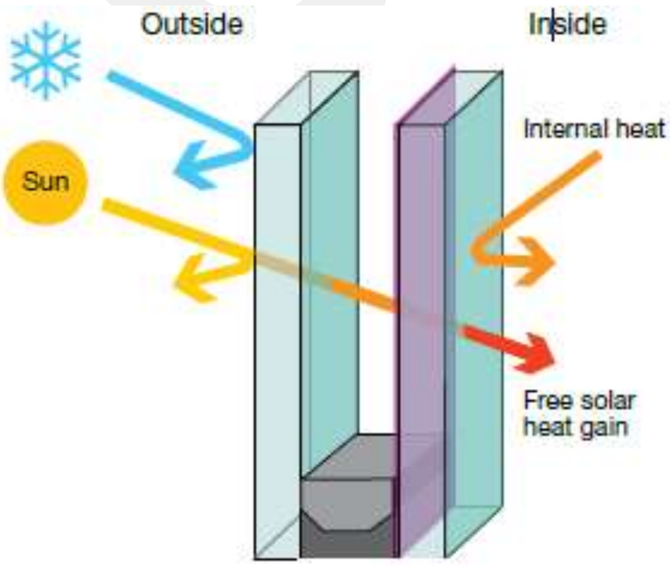

Fig 5.4. Double-glazing unit with one Low-E coating (‘Glass for’, 2009)

5.1.6. Materials for Furniture and Fabrics

- Furniture can be made from reused building elements such as doors, tables, etc.
- Wood products coming from responsibly managed forests.
- It is very important to use Adhesives, Waxes, Stains, Polishes, Varnishes and Paint with no toxic effects.
- Fabrics and carpets made from Cotton, Bamboo, Hemp, and Wool, as well as Sisal, Coir, Jute and Seagrass.

Wall paint **Metal paint** **Polish** **Wax**

Fig 5.5. Nontoxic materials (Paints, Polishes and Waxes) (Hussein, 2012, p.7).

In the table below, the materials to be used in Interior Architecture regarding environment -friendly selection criteria, as well as the related LEED Credits are presented (Table 9).

Table 9. *Classification System for the Selection of Eco-friendly Materials Used in Interior Architecture*

Area Of Usage	Selection Criteria (Given Under Chapter 3)	Material Example	Related LEED BD+C v4 Credits
Wall			
Structural	3.2. Contribution In Energy Efficiency Of Buildings (P.20)	-Bricks, Providing Higher Insulation	- EAc.18: Optimize Energy Performance
	3.3. Global Resource Limitations (P. 21)	- Gypsum Board -Concrete Blocks	- MRc.5: Building Life-Cycle Impact Reduction
Finishing	3.3. Global Resource Limitations (P. 21)	-Wood Products Of Responsibly Managed Forests	-FSC Certification
	3.4. Rapidly Renewable Materials (P. 28)	- Wall Papers, Cork and Plant Fibers	-MRc.5: Building Life-Cycle Impact Reduction
	3.7. Toxicity (P.30)	-Non-VOC Paint e.g; Water Based And Clay Paints.	-IEQc3: Low-Emitting Materials
Ceiling	3.3. Global Resource Limitations (P. 21)	- Gypsum, Foam	-MRc.5: Building Life-Cycle Impact Reduction
	3.4. Rapidly Renewable Materials (P.28)	-Cork, Bamboo, Linoleum, Rubber.	-MRc.5: Building Life-Cycle Impact Reduction
	3.7. Toxicity (P.30)	-Insulation Materials, Rock Wool, Glass Wool	-IEQc3: Low-Emitting Materials
Floor			
Structural	3.7. Toxicity (P.30)	- Natural Stone	-IEQc3: Low-Emitting Materials
	3.3. Global Resource Limitations (P. 21)	-Finished In Situ Concrete	- MRc.2: Construction Waste Management

Finishing	3.4. Rapidly Renewable Materials (P. 28)	- Cork, Bamboo, Rubber	-MRc.5:Building Life-Cycle Impact Reduction
	3.3. Global Resource Limitations (P. 21)	- Wood Products Of Responsibly Managed Forests	-FSC Certification
	3.3. Global Resource Limitations (P. 21)	-Tile Or Terrazzo: Made From Pre Or Post-Consumer Recycled Content	- MRc.2: Construction Waste Management
Windows	3.2. Contribution In Energy Efficiency Of Buildings (P.20)	-Low –E Coating -Use Of Inert Gases Such As Argon, Crypton, Etc. In Triple Pane Windows	-EAc.18: Optimize Energy Performance
Insulation	3.2. Contribution In Energy Efficiency Of Buildings (P.20)	-Cotton Batt Insulation	-EAc.18: Optimize Energy Performance.
	3.7. Toxicity (P.30)	-Rockwool, Foam	- IEQc3: Low-Emitting Materials
Furniture	3.3. Global Resource Limitations (P. 21)	- Wood Products Of Responsibly Managed Forests	-FSC Certification
	3.4. Rapidly Renewable Materials (P. 28)	-Bamboo, Cork	-MRc.5:Building Life-Cycle Impact Reduction
	3.7. Toxicity (P.30)	- Adhesives, Waxes, Stains, Polishes, Varnishes That Have Low Toxicity	-IEQc3: Low-Emitting Materials
Fabrics	3.7. Toxicity (P.30)	-The Fabric And Its Manufacturing Process Free Of Harmful Chemicals	-IEQc3: Low-Emitting Materials
	3.4. Rapidly Renewable Materials (P. 28)	-Wool, Organic Cotton, Hemp And Jute, Textiles Made From Plant Fibers, Animal Fibers And Synthetic Fibers	-MRc.5: Building life-cycle impact reduction

The criteria for the selection of eco-friendly materials can be summed up in the following table (Table 10).

Table 10. *The Criteria for the Selection of Eco-Friendly Materials in Sustainable Design*

The Criteria for the Selection of Eco-Friendly Materials in Sustainable Design	
1	Criteria of no toxicity-low VOCs: materials that have reduced toxicity condensation**.**
2	Criteria of recycled content: products with distinctive recycled content.
3	Criteria of resource efficient materials: products manufactured with reduced energy consumption and GHGs.
4	Criteria of recyclable materials: materials that are recycled at the end of their lives (cradle to cradle, instead of cradle to grave)
5	Criteria of reusable components: building components that can be reused or salvaged.
6	Criteria of sustainable sources: rapidly renewable materials harvested from sustainable sources.
7	Criteria of durable materials: materials with long life spans.
8	Criteria of moisture resistance: products that resist to wetness or inhibit the expansion of contaminants.
9	Criteria of energy efficiency: materials that help reduce energy consumption in buildings.
10	Criteria of water conservation: products and materials that help to reduce water consumption.
11	Criteria of improved IAQ: materials that promote healthy IAQ
12	Criteria of easy maintenance: materials that demand simple maintenance.
13	Criteria of regional materials: materials that are manufactured close to the project site, conserving energy for the transportation to the project site, and reducing GHG emissions.

5.2. Summary of the Developed Classification System and Criteria List for Green Materials

Table 9 illustrates the selection criteria for eco-friendly materials regarding the differing building elements found in Interior Architecture. It is seen that, various factors, which are explained in detail, in Chapter 3; including Contribution in Energy Efficiency of Buildings, Global Resource Limitations, Rapidly Renewable Materials and Toxicity, are addressed for each of these mentioned building elements. Furthermore, material examples and the related LEED v.4 criteria of BD+C scheme are given for each category of building element.

One the other hand, Table 10 illustrates the fundamental criteria for materials to be used in sustainable Interior Architecture. These criteria can be summarized as using recyclable, reusable, durable, and resource efficient materials, as well as materials that have reduced toxicity, and rapidly renewable materials that are harvested from sustainable sources.

6. CONCLUSION

As to the unconscious choices in building materials or the lack of standards in material usage, there is an increasing need to minimize the negative impacts on humans and their environment. Extracting large quantities of raw materials in order to be used in the manufacturing of construction materials, has negative impacts on the natural resources; and the excessive discharge of greenhouse gases like nitrous oxide, carbon dioxide and methane, represent a serious threat to the planet.

Such issues cause severe environmental damage to the planet due to the global temperature rise that has catastrophic effects on the climate, sea levels, biodiversity and human health. Therefore, achieving sustainable design has become the main issue in the practice of Interior Architecture. In order to accomplish this, encouraging the use of products and materials that have environmentally, economically, and socially preferable life-cycle impacts should be aimed.

Various studies demonstrate that designers mostly do not have adequate knowledge on the selection of environmentally friendly materials (Tudora, 2011; Kim and Rigdon, 1998; Hussein, 2012). Therefore, in order to decrease the impact of global warming, as well as to create healthy environments and ensure good indoor environmental quality for occupants, each project needs designers who have experience and knowledge in choosing eco - friendly materials.

The materials that are used in building construction, usually are obtained either from natural resources, industrial productions, or from recycling processes. In all cases, these materials should be environmentally friendly choices, as to the principles of sustainable design. In addition, regarding this issue, it can be stated that selection non-toxic, and non – VOC emitting materials are the most important criteria.

This study states that, the adoption of the developed classification system for selecting eco-friendly materials in Interior Architecture is required to achieve a higher level of sustainability in the construction industry.

This study also presents developed guidelines derived from the analysis of LEED Green Building Rating System, related to selection of the Eco-friendly materials. These guidelines will serve as a useful resource to keep the environment clean and healthy, by reducing the consumption of natural resources, as well as the harmful emissions involved in the life cycles of buildings and materials.

It should be noted that, since the raw materials extraction and production processes significantly contribute to the pollution of the environment, the reuse and recycling of materials and products should be promoted whenever possible. Most of the previous studies in this area had confirmed the need for the use of recycled or reused building materials, as they also reduce the cost of construction.

Finally, it can be concluded that, recyclable, reusable, durable, and resource efficient materials, as well as materials that have reduced toxicity, and rapidly renewable materials harvested from sustainable sources, can be given as the fundamental criteria for eco-friendly materials in sustainable Interior Architecture. These criteria should be taken into consideration, starting from the pre-design, or during the design stages, to ensure a safer environment to live in and a promising future for the next generations.

REFERENCES

Berge, B. (2009). *The ecology of building materials*. Routledge.

Bossink, B.A.G., Brouwers, H. J. H. (1996). Construction waste: quantification and source evaluation. *Journal of construction engineering and management*, *122*(1), 55-60**.**

BREEAM UK New Construction (NC) 2014 FAQs. v. 4.1 MANUAL

B.R.E Global (2011). BREEAM New Construction Non-Domestic Buildings Technical Manual. *Watford: BRE Global*.

Brundtland, G., Khalid, M., Agnelli, S., Al-Athel, S., Chidzero, B., Fadika, L., Singh, M. (1987). Our Common Future, Brundtland Report

Brundtland, G. H. (1985). World Commission On Environment And Development. *Environmental policy and law*, *14*(1), 26-30.

EIA, Energy Information Administration (2005). "*Annual Energy Review 2004",*Wash-ington, DC: U.S. Department of Energy from www.eia.doe.gov/emeu/aer/contents.html

Elgendy, K. (2010). Comparing Estidama's Pearl Rating System to LEED and BREEAM. http://www. carboun. com accessed, 19(05), 2015.

EPA Home. Water Sense. Retrieved February 2, (2016). from http://www.epa.gov/WaterSense/pubs/supply.html.

Freeman ,R.J. (2015). *Beginners guide to green building.*

Glass for Europe, (2009). Europe's Manufacturers of Building, Automotive and Transport Glass, *Low-E Insulating Glass for Energy Efficient Buildings*: How policy-makers could save energy and significantly reduce CO2 emissions to meet EU targets for 2020. P3.

Gluch, P., Stenberg, A.C. (2006). How do trade media influence green building practice?. *Building Research & Information*, *34*(2), 104-117.

Godish, T. (2016). Indoor environmental quality. CRC press.

Graedel, T. E., Allenby, B. R. (1995). Industrial Ecology, Prentice. Hall: New Jersey, U.S.A.

Greenhouse gas (n.d). Retrieved June 4, 2016 from https://en.wikipedia.org/wiki/Greenhouse_gas

Harputlugil T. (2013). *Leadership in Energy and Environmental Design (LEED),* 11. Ulusal tesisat mühendisliği kongresi – 17/20 nisan 2013/izmir.

Hartley, D.L. (1990). Perspectives on renewable energy and the environment J.W. Tester, D.O. Wood, N.A. Ferrari (Eds.), Energy and the environment in the 21st Century, MIT, Massachusetts.

Hussein, M. F. (2012). The Ideal Usage of Sustainable Materials and Local Resources of the Interior Space Design in Jordan. *Journal of Civil Engineering and Architecture*, *6*(8), 1047.

Kim, J. J., Rigdon, B. (1998). *Sustainable architecture module: Qualities, use, and examples of sustainable building materials*. National Pollution Prevention Center for Higher Education.

LEED (2011). *LEED 2009 for New Construction and Major Renovations Rating System with Alternative Compliance Paths for Projects outside the U.S.* (Updated November 2011) U.S. Green Building Council, Washington DC.

Levin, H. (1991). Critical building design factors for indoor air quality and climate: current status and predicted trends. *Indoor air*, *1*(1), 79-92.

McHenry, P. G. (1984). *Adobe and rammed earth buildings: design and construction*. University of Arizona Press.

Rezaallah, A., Bolognesi, C., Afghani, K. R. (2012). Green Design; A Necessity for Future of Social Housing. In *IAHS XXXVIII World Congress on Housing, Istanbul, Turkey*.

Roberts, T. (2010). Non-US Regional Priority Credits Added to LEED. Retrieved from.http://www.leeduser.com/topic/non-us-regional-priority-credits-added-leed

Roodman, D. M., Lenssen, N. K., Peterson, J. A. (1995). A building revolution: how ecology and health concerns are transforming construction (pp. 11-11). Washington, DC: Worldwatch Institute.

Rousseau, D. (2009). "*Sustainable Built Environment*": Environmentally friendly building materials. United Nations: Encyclopedia of Life Support Systems, volume, 1.

Suzer O., Yılmaz M. (2010). An Innovative Waste Management System 'Cierra Recycling', and Its Product as a Sustainable Building Material. *International Sustainable Buildings Symposium (ISBS), 26-28 May 2010, Ankara, Turkey*, Gazi University

Suzer, O. (2015). A comparative review of environmental concern prioritization: LEED vs other major certification systems. *Journal of environmental management*, *154*, 266-283.

Tudora, A. C. (2011). Assessments Criteria of Building Materials from Ecological Point of View. *Buletinul Institutului Politehnic din lasi. Sectia Constructii, Arhitectura*, *57*(4), 129.

US Green Building Council (USGBC), (2009). LEED 2009 for New Construction and Major Renovations Rating System (v.3), Washington, USA. Retrieved from. http://www.usgbc.org/Docs/Archive/General/Docs5546.pdf

US Green Building Council (USGBC), (2010). Regional Priority Credits,Washington,USA.Retrieved from http://www.usgbc.org/Docs/Archive/General/Docs8156.pdf [accessed12. 10.16.].

US Green Building Council (USGBC). Directory. Retrieved from: http://www.usgbc.org/projects.

USGBC, U.S. Green Building Council. Retrieved (2016) from http://www.usgbc.org/credits/new-construction/v4/material-%26-resources.

Vatalis, K. I., Manoliadis, O., Charalampides, G., Platias, S., Savvidis, S. (2013). Sustainability components affecting decisions for green building Projects. *Procedia Economics and Finance, 5*, 747-756.

APPENDICES

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WORK EXPERIENCE

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