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und Wirtschaft Berlin

University of Applied Sciences

Cost-benefit impacts of sustainable buildings in Iran

Master thesis

International Master of Science in Construction and Real Estate Management

Joint Study Program of Metropolia UAS and HTW Berlin

Submitted on 24.08.2018 from

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Background

In recent decades, there has been a growing concern regarding environmental issues, and consumption of energy and resources in the building sector. Sustainable constructions are the response to growing environmental concerns. Some of the major topics in sustainable building market readiness and some cost-related barriers such as higher initial design and construction costs, extra costs of searching for green alternatives and certification processes, a long payback time and a difficulty of defining quantifiable requirements during the procurement process has mentioned by Z. Gou, S.S.Y. Lau. The extra costs and related risks of sustainable construction may discourage initial investors from commitment to green attributes [Z. Gou, S.S.Y. Lau]. Hwang and Tan in 2012 indicated that the ambiguity of the real costs and benefits is a major impediment to the development of sustainable construction.

Cost-benefit analysis is a quantitative economic analysis method which evaluates profitability and return of investments for alternative design options [Commonwealth of Australia, 2006]. Similarly to traditional financial strategy and performance measurements, sustainable cost-benefit studies examine the correlations between the strategies and performances to discover relationships between costs and benefits for decision making. Cost-benefit studies, though, aim to identify relationships among costs as a consequence of sustainable strategies and benefits as a consequence of sustainable construction performances. In other words, the extra costs of these buildings are evaluated against the extra financial benefits.

Research questions and objectives

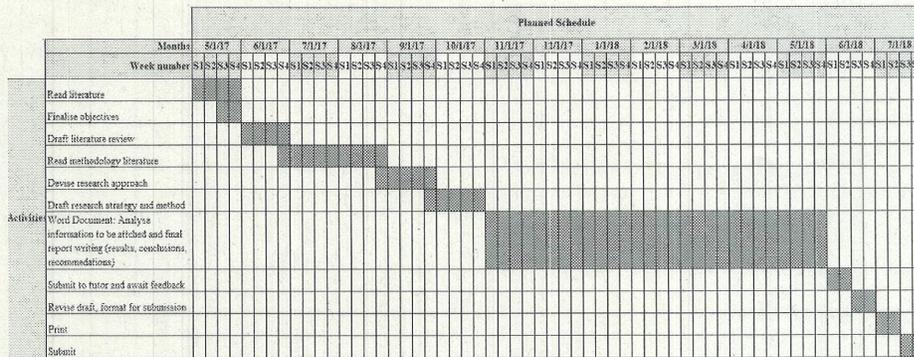
Although the goal of this study is to investigate the role of sustainability in construction industry, it shows the cost benefit in this kind of construction. The following statements list the objectives of the study:

1. What is the benefit of sustainable construction?
2. Is sustainable construction profitable?
3. How long does it take to get back the investment cost in sustainable construction?
4. How would be the cost trend of sustainable construction during life time service?

Method

The purpose of this study is to demonstrate the sustainable construction and also illustrate the impacts of cost benefits with using the experiments of other researches as well as experts. In this study, I will present the variation of cost benefits estimation and depict the probable various methods.

Timescale

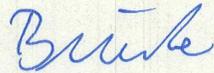


Resources

Although by using either different case studies or articles and also referring to the various books, I will collect data and information by researching through the construction industries outcome which are available.

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Prof. Dieter Bunte



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Vahid Naseri Abkooh

For the
Chairperson of the Examination Board

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REQUEST TO CHANGE THE TITLE OF THE FINAL THESIS

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I wish to request for the following change to the title of my thesis.

Previous title:

cost benefit impacts of sustainable construction
in Germany

New title to be confirmed:

Cost-benefit impacts of sustainable buildings
in Iran.

Please note that changing the title of the final thesis does not constitute a rejection of the topic as defined by § 21, no. 2 of HTW's Examination Framework Regulations!

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Berlin, 08.08.18

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Abstract

The green building could be a building with different usage. In the meantime, either entire or a considerable section of the production cycle of the energy as well as the consumption of it occur inside the building. Meanwhile, the sustainable building, or the green building, is consisted of the green materials for the environment, and the modern technologies related to the green energy. Sustainable design, protection, and water consumption saving, controlling the energy, environmental protection, the quality of the interior space of the building and the protection of resources and materials are the general principles of each sustainable building. The purpose of creating a sustainable or a green building is utilizing the new durable construction equipment and materials so that the building itself can produce the energy. In this master thesis, comparing the sustainable building with the conventional building in Iran regarding cost and benefit, energy consumption, environmental protection, and materials is described. It is also expressing the necessity of implementing the sustainable building in Iran. The results show that although the initial cost of the green building in Iran is about 14 percent more than the conventional building, the energy consumption has an impressive reduction. Also, there will be a significant reduction in final costs for sustainable buildings, and this money will back during the lifecycle of the building. So the simple payback of the sustainable building in Iran is around 14 years.

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List of Abbreviations

LEED	Leadership in Energy and Environmental Design
BREAM	Building Research Establishment Environmental Assessment Method
ESD	Ecologically Sustainable Development
GHG	Greenhouse Gas
USGBC	U.S. Green Building Council
IGBC	Iran Green Building Council
CFCs	Chlorofluorocarbons
HVAC	Heating, Cooling, Air-conditioning, and ventilation units
DGNB	German Sustainable Building Council
ASTM	American Society for Testing and Materials

1. Introduction

1.1 Background

These days, the concern about environmental issues in the building sector has been grown. In the meantime, the resources and energy consumption has become important in the life. The solution is found in the sustainable constructions which anyone can see them quickly in the nearby. Some people say sustainable buildings cost more than conventional buildings, and the others say the extra cost is valuable because of energy saving which will be gained during the life cycle. The additional cost could be due to the certification process, specific materials, and also could be because of demands of green building in the market. (Z. Gou) indicated some topics about sustainable buildings such as higher initial design and the cost of construction, the extra cost of searching for green alternatives and certification process, payback time and the problems which are occurring during the procurement.

The mentioned researcher indicated that the additional cost, as well as the probable risks of sustainable construction, may not courage the investors to be responsible for the sustainable building.

Hwang and Tan in 2012 indicated that the ambiguity of the real costs and benefits is a significant impediment to the development of sustainable construction.

Meanwhile, the payback will be influenced by the strategies which will be taken for the sustainable buildings.

Furthermore, sustainable building not only improves the quality of our environment but it also has many economic benefits as well. By using sustainable materials, reducing energy consumption, and improving water efficiency the sustainable building brings some advantages such as:

- Sustainable Market will expand
- The operation cost will decrease
- The life cycle of the building will optimize

- The property value will increase

Therefore, the analysis of cost-benefit for sustainable buildings is a method to evaluate the profitability and also to assess if the investment has returned for different design options.

The traditional financial strategies measure the performance of the building. Meanwhile, in the sustainable buildings, the aim is to examine the cost-benefit which is between the strategy and executions to identify the harmony between costs and benefits to decide on constructing a building.

Cost-benefit impacts, though, lead to discovering the relationships within cost which are the consequence of sustainable building and benefit which is the consequence of performances in sustainable building. In other words, the extra costs which maybe would happen upon green buildings will be evaluated against the additional benefits of financial.

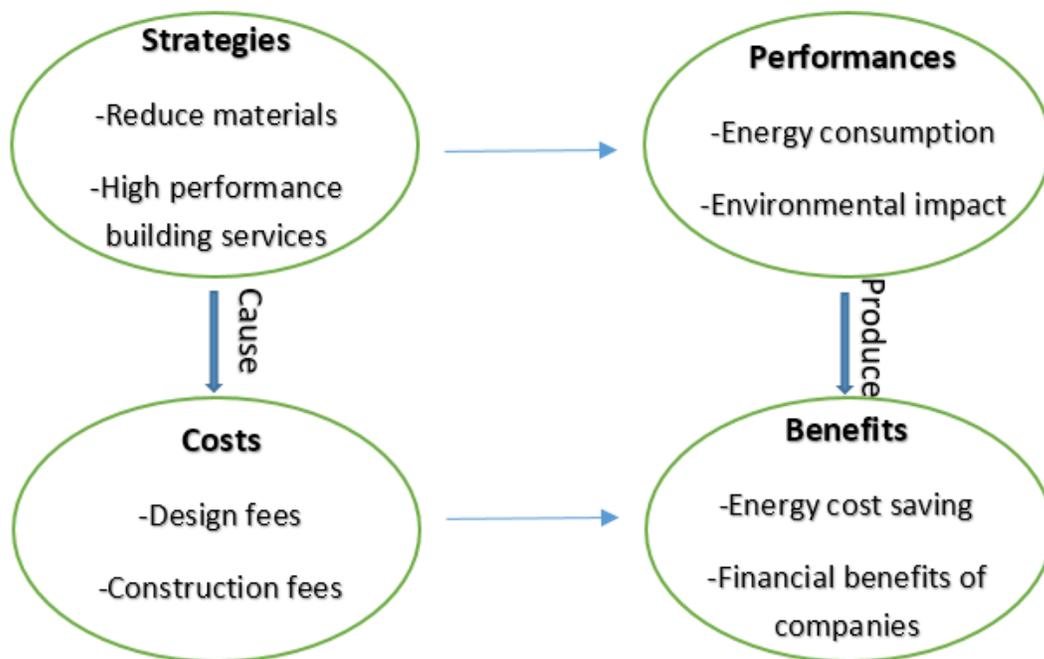


Figure 1. Flowchart of green cost-benefit methodology approach¹

¹ (M. Khoshbakht, Z. Gou, K. Dupre, 2016)

On the other hand, there are several pieces of evidence that financial rewards will be provided for the owners of the sustainable buildings as well as the occupiers.

Firstly, the annual energy consumption is less in sustainable buildings so the annual cost of energy would be less consequently. Secondly, the annual cost of water consumption, maintenance, and the other operating cost will decrease in green buildings.

1.2 Aim of the study

The primary goal is to investigate the role of sustainability in the construction industry, and shows the cost- benefit in this kind of constructions to solve the environmental problems, energy consumption, and resources in the building sector.

As already mentioned, there are different methods to create the building sustainably and lead it to be profitable. This research will illustrate how to make the building sustainable to help the environment as well as the cost and resources. Besides, the aim is to find existing case studies of sustainable buildings, develop a case study in Iran, analysis, and comparison between these different case studies as well as comparing the sustainable buildings with the conventional ones.

Although the development of a case study among Iranian sustainable buildings helps to identify the difficulties of a green building in the country, it helps to find some strategies to make the buildings sustainable.

Lastly, the suggestion and recommendation will be shown in the last chapter with the hope of having a better environment and better sustainable market in Iran.

In this research, the following keywords will be searched for the literature review: sustainable buildings, sustainable cost- benefits, green buildings and financial benefits, and so on. The goal is to find the most reliable reports, articles, books, and journals to develop the research academically.

1.3 Research questions

The questions which this research will address are:

- How could a building be sustainable?

- What is the benefit of sustainable buildings?
- What is the relation between the cost and the benefit of sustainable buildings?
- How are the average of cost premium and simple payback in non-residential sustainable buildings?

2. Methodology

The methodology of the master thesis is described in this chapter. The methodology covers the environmental benefit of sustainable construction such as energy consumption saving. In the meantime, the economic aspect of the sustainable construction is described.

The master thesis is started by searching for some keywords for the literature search such as 'conventional buildings, cost and the benefit of sustainable buildings and financial benefits of sustainable building' to collect the most accurate and reliable reports in the review by referencing the publications such as books, articles, reports, conference papers, and websites.

In this master thesis, the aim is to describe the sustainable buildings as well as the cost of this kind of buildings. Besides, the master research analyzes the cost and benefit of existing nonresidential green buildings.

In the meantime, in the master thesis, the impact of buildings on the environment will be illustrated in the related literature review chapter. Meanwhile, the definition of sustainable buildings, as well as the conventional buildings, will be explained in the third chapter. Different standards of sustainable buildings also will be mentioned.

Afterward, the two existing case studies which are about the nonresidential buildings, one is the school, and another one is the library, will be analyzed. In the next step, the case study of an office building in Iran will be done and be compared with the other existing case studies. Meanwhile, the difference between related sustainable buildings standards will be illustrated in the further chapters.

Sustainable buildings are not typical in Iran, so the aim is to suggest or recommend some strategies to courage the different stakeholders to make the buildings sustainable. The strategies will be identified and be shown in the last chapter.

Besides, the references are available and provided in the footnotes throughout the report which will be directed to the publications and databases for further information.

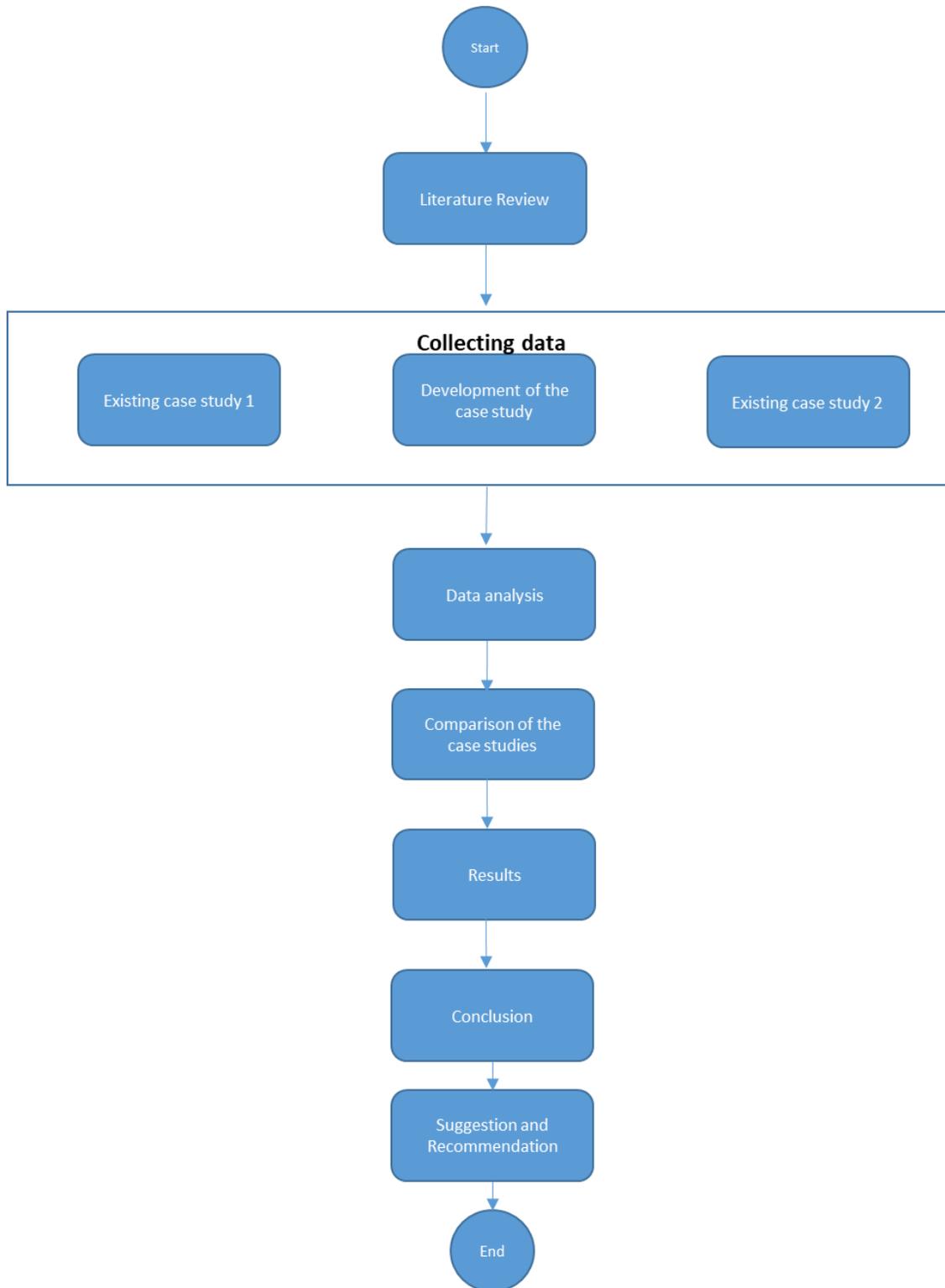


Figure 2. The diagram of the methodology²

² Own figure

3. Related literature and theoretical focus

In this chapter the impact of the cost-benefit is described, as well as the concepts of sustainability and sustainable construction and also conventional buildings. Besides, sustainability assessment tools are shown, followed by the current and future state of the sustainable building. Finally, sustainable building in Iran will be presented. The literature research aims to provide a basis and a general view of the research.

3.1 Impacts of buildings on the environment

Today, the environment is profoundly affected by the activities of people. Humans use natural resources at a faster rate than it can be replenished.³ Humans also produce more waste products (such as the emissions of carbon dioxide) than our atmosphere can absorb. Now, there is no doubt that human-induced climate change occurs.⁴ The world's climate changes and will continue at rates that have been unknown in recent human history.⁵ The built environment has a direct and vast influence on the ecosystem more than any other human undertaking.⁶ Research of the United Nations Environment Programme (2009)⁷ showed that buildings are responsible for one-third of the global greenhouse gas (GHG) emissions in all over the world and responsible for over 40% of the total energy use. According to Levine et al. (2007), the deflagration of energy resulting from fossil fuels in buildings produced an estimated 3 Gt⁸ carbon dioxide (CO₂) in 2004, compared to 8.6 Gt CO₂ by all energy users. Mainly the concern is the rising rate of emissions resulting from the built environment, mostly through the use of energy. Between 1970 and 2010 the GHG emissions have more than doubled and reached 9.18 Gt CO₂ in 2010 (IPCC, 2014b). Thus, by considering the current development in new constructions and the existing unsustainable stock of buildings in all over the world, it becomes evident that if the current condition is still the same, GHG emissions resulting from buildings will again be doubled in the following 20 years (Levine et al., 2007). In

³ (UNEP, 2000)

⁴ (IPCC, 2014)

⁵ (Adger, 2003)

⁶ (Kibert, 2004)

⁷ (UNEP, 2009)

⁸ GT CO₂ = 1.000.000.000-ton Carbon Dioxide

order to diminish the worst case scenarios of climate change, GHG emissions have to be reduced by at least 25% within 11 years and reduced by 50% within forty years. Fortunately, the built environment has the most critical potential to significantly reduce their GHG emissions as compared to any other primary emitting sector.⁹ With the use of some technologies, the energy consumption in buildings can be reduced around 30% to 80% during the lifecycle of the building.¹⁰

3.2 Conventional buildings

Many people use the term 'Conventional Build', or building, to imply the use of masonry for the outside walls, where 'masonry' infers the use of bricks and concrete blocks for these. However, this could also include stone, aerated lightweight concrete blocks, breeze blocks, empty clay pots, 'no-fines' concrete, and many other materials. These could be used as the structural elements of the building, but they could also provide weatherproof 'rain screens', or architectural features for the facade, with no other purpose.¹¹



Figure 3. Masonry House with Timber Roof¹²

⁹ (Robichaud, L.B., & Anantatmula, 2010)

¹⁰ (UNEP, 2009)

¹¹ (Benfield, low energy buildings, 2010)

¹² (Benfield, low energy buildings, 2010)

3.2.1 Conventional building method

Conventional building method is defined as materials of the building that are prefabricated on site through the processes of timber or plywood formwork installation, steel reinforcement, and cast in-situ. Conventional buildings are mostly building of reinforced concrete frames.¹³ The traditional construction method uses wooden formwork. Meanwhile, it is much more costly for construction which includes labor, raw material, transportation and low speed of construction time. ¹⁴

Traditional buildings consume or are responsible for:

- 45% of the world's total energy use
- 50% of all materials and resources
- 50% of the wood used in North America
- 35% of the world's CO2 emissions
- 80% of potable water use
- 25% of freshwater withdrawal including power plants
- 40% of municipal solid waste destined for local landfills
- 50% of ozone-depleting CFCs still in use.^{15,16}

However, the consciousness of the influence that buildings have on the environment seems to develop, and consequently, research in the design and construction of buildings have focused on how sustainability measures can reverse the impact of climate change. Numerous types of research have shown that sustainable building practices can remarkably reduce the energy consumption and GHG emissions resulting from the built environment. For example, the research of Kats (2003) among 60 LEED rated commercial buildings showed that on average sustainable buildings use 25% to 30%

¹³ (Andres, C. K., and R. C. Smith, 1998)

¹⁴ (Badir, Kadir and Ali., 1998)

¹⁵ (Roodman, David Malin and Nicholas Lenssen, 2004)

¹⁶ (Personal correspondence with Rob Watson, 2004)

less energy as compared to conventional buildings. Was approved by the research of Watson (2009) which illustrates that LEED-certified commercial buildings use 25% less energy during the operational period of a building than comparable buildings. Between the period of 2009 and 2020, these energy savings will result in 78 million tons of emissions avoided. Other studies demonstrate that sustainable building practices can reduce a building's energy consumption by 42% (Lockwood, 2006) and even 50%.¹⁷

Therefore, the consciousness of the potential of sustainable buildings to positively influence the environment is developing and has now reached the governments, corporate world, and industries. As a result, governments increasingly adopt sustainable building standards and regulations and provide incentives for the implementation of sustainability practices. Research shows that every year more projects search for environmental certification, which indicates that the demand for sustainable buildings is also increasing in the corporate world and industries.¹⁸

3.3 Definition of sustainability

Brundtland Commission indicated on page 37 in 1987 that being sustainable is not only just diminishing the carbon footprint and saving energy. Sustainability is about “development that faces the needs of the current moment without reaching an agreement on the ability of future generations to meet their own needs. It means detecting a balance between economic growth, social responsibility and the capacity of natural resources (Dyllick and Hockerts, 2002) . A balance between these elements has to be created because they are intertwined and influence each other (Meadows et al., 1972). The harmonization of these three objectives also refers to the Triple Bottom Line, or the three P's: people, planet, and profit, which Elkington (2004) explains as creating financial value for the organization while taking care of the staffs, stakeholders, and society, and doing no harm to the environment. Sustainability is not a new concept, the quest for a balance in the three P's has been a challenge for over 150 years (Dyllick and Hockerts, 2002). However, in the past decades, sustainability has significantly grown in

¹⁷ (Robichaud, L.B., & Anantatmula, 2010)

¹⁸ (Robichaud, L.B., & Anantatmula, 2010)

importance and is considered to be one of the most common challenges in our time (Silvius, 2012). Organisations are being increasingly pressured to shift their focus from solely being responsible for the economic performance towards their shareholders, to be responsible for the sustainability performance of the organization towards all stakeholders (Visser, 2002 cited in Silvius, 2012). Proactively or reactively, organizations are searching for ways to merge the concepts of sustainability in their marketing, their communication, their actions and their resources (Silvius, 2012). Not only due to pressure from society, or from a humanitarian standpoint, but also because it has shown multiple advantages and even generates economic value for organizations.¹⁹

3.4 Sustainable buildings

“Green” or “sustainable” buildings are sensitive to:

- Environment.
- Resource & energy consumption.
- Impact on people, quality, and healthiness of the nearby.
- The financial impact, cost-effectiveness from a full financial cost-return perspective.
- The world at large, a broader set of issues, such as groundwater recharge and global warming, that a government is typically concerned about it.²⁰

Green Building, also known as Green Construction or Sustainable Building, refers to structures and processes that remain environmentally responsible and resource-efficient throughout the building’s lifecycle. This topic covers everything from sighting to design, construction, operation, maintenance, renovation, and demolition. Different rating systems exist to evaluate the sustainability level of buildings, such as LEED (US & Canada), (BREEAM (UK), HQE (Fr), DGNB (Germany), Green Star (Australia)).²¹

Green Building is all about striking a balance between building and sustainability. Designers, architects, engineers, IT-specialists and end users work closely together at

¹⁹ (Holliday , 2001)

²⁰ (Greg Kats, 2003)

²¹ (White Paper, 2016)

all the stages of the building project. Meanwhile, they analyze customer requirements and work out solutions that are not only economical, durable and comfortable but environmentally responsible and energy efficient, or 'green,' too. Hence the notion of 'Green Building.'²²

3.5 Green Building Best Practices

Green Building is an approach to reducing the impact of buildings on the environment and human health throughout and beyond their lifecycle. In such a Building, resources are used more efficiently to create and operate homes, commercial facilities or institutions, which are more energy-efficient and healthy for inhabitants. It includes water and electricity meters, carbon dioxide presence detectors, intelligent light management and HVAC (heating, cooling, air-conditioning and ventilation units), use of low-impact building materials and materials for finishing and interior design. Green roofs, rain gardens, use of solar, wind and geothermal power all play an important role in green buildings. Meanwhile, production of waste and toxic substances also decrease in sustainable buildings. Also, Information and Telecommunication Technologies are an essential part of today's building infrastructure; it is worth considering how these can play a part in 'greening' the Building.²³

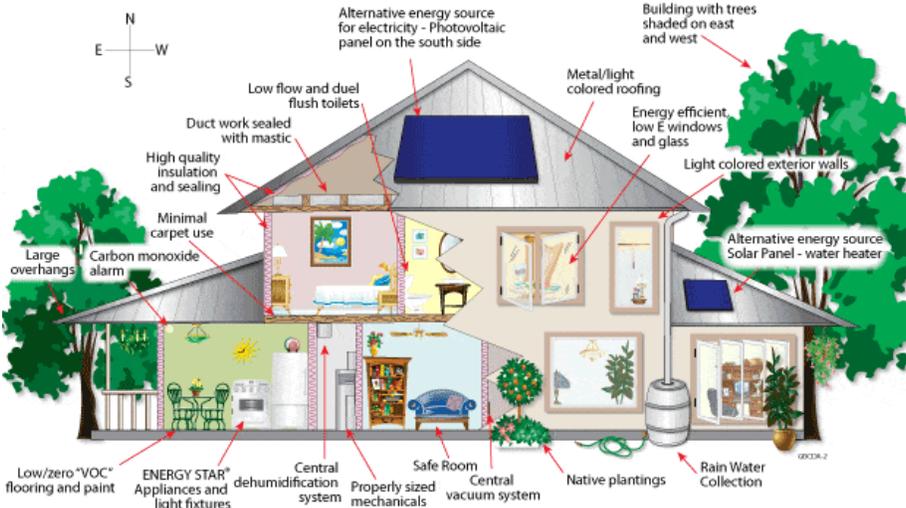


Figure 4. A green building design²⁴

²² (White Paper, 2016)

²³ (White Paper, 2016)

²⁴ (FI, 2018)

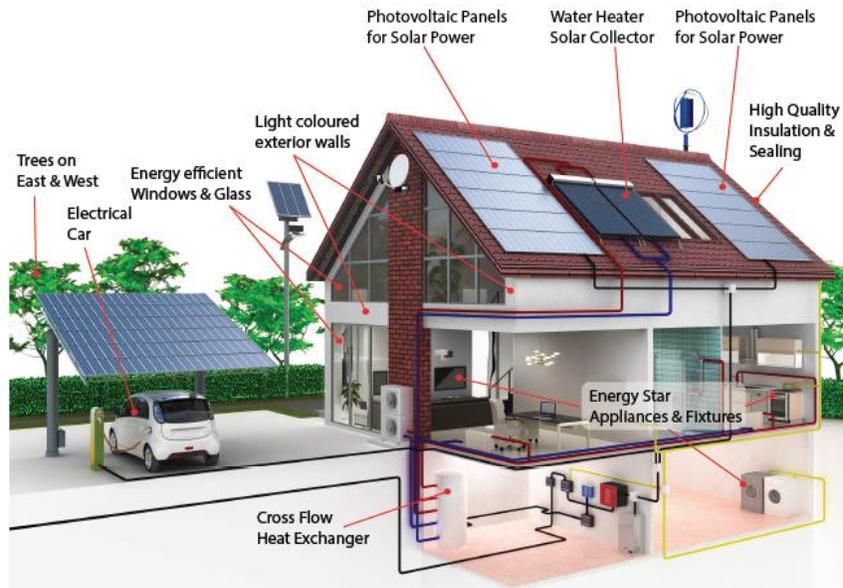


Figure 5. A green building²⁵

However, California’s Executive Order D-16-00 appoints a robust set of sustainable building aims such as “to the site, design, deconstruct, construct, renovate, operate, and maintain state buildings that are models of energy, water, and materials efficiency; while providing healthy, productive and comfortable indoor environments and long-term benefits to Californians.”

In fact, this green building Executive Order requires consideration of externalities, economic and environmental performance measures, life cycle costing, and a whole building integrated systems approach when making sustainable building funding decisions.

Moreover, these aims for sustainable building design include not only perceptible savings associated with energy, water, and waste efficiencies, but also softer benefits, such as human health and productivity, impact on the environment, and incorporation of recycled components.²⁶

Also, the SBTF published a report in 2001. The name of the report is Building Better Buildings which is a Blueprint for Sustainable State Facilities²⁷ the first in a series of

²⁵ (White Paper, 2016)

²⁶ (Governor’s Executive, 2000)

²⁷ (uilding Better Buildings, 2001)

reports that will document the progress of California state government in implementing the Governor's sustainable building goals. The Blueprint remarks that sustainable buildings are usually called green building as well as high-performance buildings.

Meanwhile, the US Green Building Council (USGBC)²⁸ uses the term "green" to distinguish a building with the same aims as those shown in the Blueprint.

Further, other initiatives, such as New York's High-Performance Building Design Guidelines²⁹, use the term "high performance" to explain virtually the same set of building features. The High-Performance Guidelines set particular attention to the use of advanced technology, or smart infrastructure, and its effect on tenant ability to control key building comfort measures such as temperature and light levels to improve performance.³⁰

This master thesis will use "sustainable building" and "green building" synonymously.

Therefore, sustainable design practices have been applied in American buildings for millennia, as evidenced in the delicate structures of the Hopi Indians a thousand years ago. However, the term sustainable or green architecture as a modern, integrated design philosophy appears to be very recent. In the meantime, the first references to "green architecture" and "green building label" reportedly appeared in the British publication *The Independent* in London in early 1990, followed by the first American use of the term "green architecture" in the middle of 1990, on the editor's page of *Architecture* magazine.³¹ The American Institute of Architect's Committee on the Environment started in 1989.³²

Therefore, the city of Austin established the first green building strategy in the United States in 1991, but there are now several such programs nationally. The Green Building committee of the American Society for Testing and Materials (ASTM) also formed in 1991. Thus, the modern green building movement appears to be little over a decade old.

²⁸ (United States Green Building Council, n.d.)

²⁹ (Construction, New York City Department of Design and, 1999)

³⁰ (Alan Traugott, 1999)

³¹ (Nathan Engstrom, 2002)

³² (COTE, n.d.)

It is therefore effective that there is already an emerging national consensus on the description of a green building and a rapidly increasing number of green projects in both the public and private sectors.³³

While there is not exact “correct” weighting of green attributes, there is a broad consensus both about the general attributes that constitute greenness, as well as the relative weighting that these different attributes should receive. However, the definition of a sustainable building is subjective. There is no universally accepted way to compare such diverse green attributes as, for example, improved human health, reduced the pollution of water, and reduced cutting the forest.

Meanwhile, different green building programs balance several dimensions of “greenness” through an essentially subjective weighting. For example, Green Globes, a US online assessment tool for benchmarking the greenness of building performance, attributes 34% of the weighting of building greenness to energy use, more than the USGBC’s Leadership in Energy and Environmental Design (LEED) Rating System’s 29%. Because of the huge range of “green” attributes considered, no single scientific denominator exists, and weighting reflects consensus best judgment rather than scientific determination.³⁴

The range of definitions of what constitutes a green or sustainable building includes:

- The British Research Establishment Environmental Assessment Method (BREEAM) was launched in 1990 and is increasing in use.
- Canada’s Building Environmental Performance Assessment Criteria (BEPAC) began in 1994. The system was never fully accomplished due to its complexity.
- The Hong Kong Building Environmental Assessment Method (HK-BEAM) is currently in pilot form.
- The US Green Building Council (established in 1993) began development of the Leadership in Environmental and Energy Design (LEED) Green Building Rating System

³³ (Greg Kats, 2003)

³⁴ (Greg Kats, 2003)

in 1994. Version 2.0 of the LEED standard was formally released in May 2000; Version 2.1 was released in November 2002.³⁵

US state or regional green building guidelines include:

- High-Performance Building Guidelines in New York in 1999.
- Guidelines for Creating High-Performance buildings in Pennsylvania in 1999.³⁶

Also, there are a dozen or more local applications of LEED, generally adding more stringent requirements as part of state certification. Federal work on green buildings, coordinated by DOE's Federal Energy Management Program, has also developed vital programs and resources on green building best practices.³⁷

The increasing attention to sustainability is also visible through the advent of sustainable buildings. In the literature, multiple definitions of sustainable buildings are described. According to Lockwood (2006), sustainable buildings are buildings that have a less adverse environmental impact as compared to conventional buildings. These buildings are environmentally responsible throughout the whole lifecycle of a building, from siting, design, construction, an operation to destruction. Kats (2003) adds that they are designed in order to reduce the negative impact on human health and well-being. Furthermore, Robichaud and Anantatmula (2010) state that sustainable buildings can be considered as a philosophy that seeks to:

- minimize environmental impact
- enhance the health, wellbeing, and productivity of the users
- increase the return on investment to developers, and the community
- consider the lifecycle of the building during the planning and construction phase.

Looking at these three definitions, the definition of Robichaud and Anantatmula (2010) seems to be the most complete. According to this definition, sustainable buildings integrate all three pillars of sustainability during the lifecycle of a building, from sitting to destruction. It is worth noting that the term 'sustainable building' has been used as a

³⁵ (Greg Kats, 2003)

³⁶ (Greg Kats, 2003)

³⁷ (Greening Federal Facilities, 2001)

synonym for 'green building,' 'high-performance building,' 'sustainable design,' and 'integrated design.'^{38,39}

3.6 Assessment tools for sustainable buildings

Even though there is a consensus regarding attributes that shape sustainable buildings, there is no universally accepted way to compare and qualify these attributes. There are however a number of methods available that assess the sustainability performance of buildings, with the most representative being Leadership in Energy and Environmental Design (LEED, United States) and the BRE Environmental Assessment Method (BREEAM, United Kingdom), which were both developed in the 1990's (Lee and Burnett, 2008). Other regularly used sustainability assessment tools are Green Star (Australia), Green Mark Scheme (Singapore), Comprehensive Assessment System for Built Environment Efficiency (Japan), Pearl Rating System for Estidama (United Arab Emirates), and Green Building Index (Malaysia). The green building council developed all these tools in each region or country. The evaluation is directed by authorized professionals appointed by the green building councils. The World Green Building Council has been created in order to coordinate the various green building councils in the world. There are numerous sustainability assessment tools; the two most popular tools will be explained.⁴⁰

3.6.1 LEED

LEED is a third-party certification program designed and operated by the U.S. Green Building Council (USGBC). LEED stands for 'Leadership in Energy and Environmental Design' and is designed to set standards and measure the sustainability performance of buildings in construction and operation. LEED focuses on five areas, being sustainable site development, water savings, energy efficiency, selection of materials, and indoor environmental quality (Robichaud and Anantatmula, 2010).

However, organizations earn 'points' for environmental interventions in each of the above five mentioned areas for receiving the certification. When enough points are

³⁸ (Zuo, J.A. & Zhao, Z.Y., 2014)

³⁹ (Robichaud, L.B., & Anantatmula, 2010)

⁴⁰ (Nadine Wessels, 2014)

accumulated, they get awarded with a certification in a certain level: Certified, Silver, Gold, and Platinum (where platinum is the highest). In 2013 already 50.000 buildings worldwide had been certified or were in the certification process (Roudman, 2013).⁴¹

The LEED system was developed primarily on a voluntary basis and has been adopted widely for green building projects. The figure below illustrates the quick growth of LEED for new construction between 2000 and 2006 (Yudelson, 2008). In the meantime, it has grown to encompass more than 14,000 projects in the US and cover over 30 countries (WGBC, 2009). However, there are more than 6,900 LEED-certificated buildings all over the world (WGBC, 2009). Also, it is predicted that the annual CO2 saving from LEED building is approximately 3 million tons from energy efficiency and renewable energies. Besides, it will grow to 130 million tons per year by 2020 and 320 million tons annually by 2030 (Watson, 2009). It was expected that the cost to achieve greener building exceeded conventional buildings. However, based on a study of 40 US offices and schools with the LEED standard, it was found that the costs of reaching LEED standards system are 0.66% for the first level, 1.9% and 2.2% for silver and gold respectively. However, the cost of reaching the highest level of LEED (platinum) is a 6.8% premium cost. Nevertheless, these cost premiums were substantially lower than the previous estimation, as shown in Figure below (Kats, 2003).⁴²

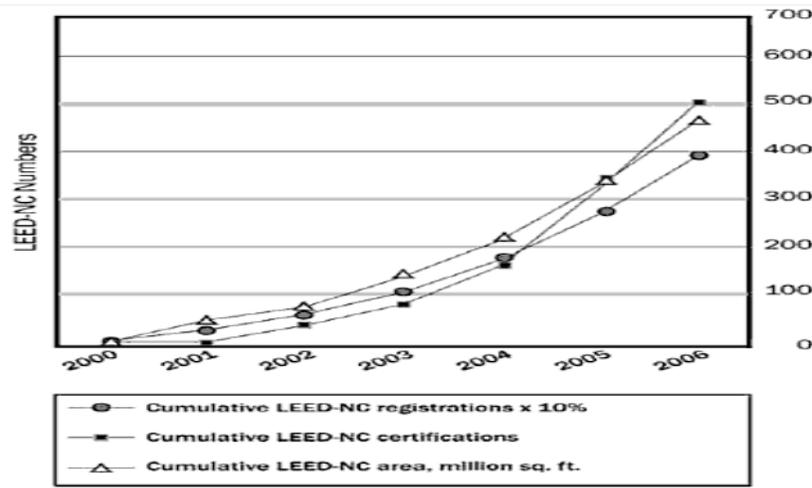


Figure 6. the growth of LEED⁴³.

⁴¹ (Nadine Wessels, 2014)
⁴² (Fangzhu Zhang & Philip Cooke, 2009)
⁴³ (Yudelson, 2008)

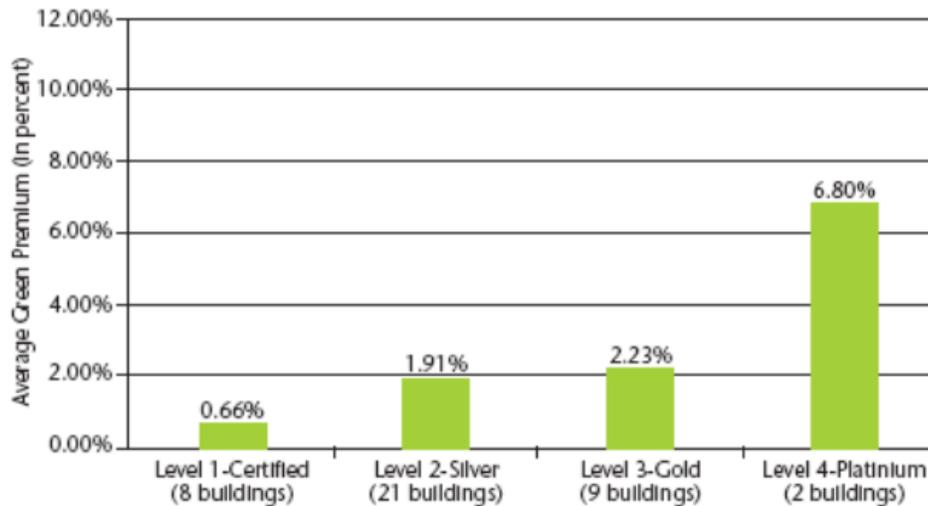


Figure 7. the level of green certification⁴⁴

In fact, green buildings provide financial benefits that conventional buildings do not. The benefits are in lower energy consumption, water consumption, and waste reduction costs, lower CO₂ emissions and increased productivity and health, saving about \$50-\$70 per square foot in a LEED building (Kats, 2003). Further, the government is playing a crucial role in promoting green building through regulations. For instance, LEED gold certificated buildings will gain priority in planning permission. Finally, the tax credit is another incentive approach for the promotion of green building.⁴⁵

A new LEED system for rating neighborhood development is being developed by USGBC to integrate the principle of smart growth, new urbanism and green building into the first standard for neighborhood design (WGBC, 2009) which may be of particular interest to city and regional planners because of their focus on building position, landscape and community sustainability. So far, there are many building assessment systems in the world, and no single method has emerged as the green building industry standard in the world. Each assessment system has focused on different aspects of practice such as health, technology or environment. They all integrate environmental and sustainability issues into the building industry.⁴⁶

⁴⁴ (Kats, 2003)

⁴⁵ (Fangzhu Zhang & Philip Cooke, 2009)

⁴⁶ (Fangzhu Zhang & Philip Cooke, 2009)

Category	Saving (per square foot) (based on 20-year net present value)
Energy savings	\$5.8
Emission savings	\$1.2
Water savings	\$0.5
Operations and maintenance savings	\$8.5
Productivity and health benefits	\$36.9-\$55.3
Subtotal	\$52.9-\$71.3
Average extra cost of building green	(-\$3 -\$5)
Total 20-year net benefit	\$50-\$65

Table 1. Financial benefits of green buildings⁴⁷

3.6.2 BREEAM

BREEAM is an evaluation tool for best practice in sustainable building design, construction, and operation. BREEAM stands for 'Building Research Establishment Environmental Assessment Method' and is designed by the Centre for Sustainable Construction, part of the Building Research Establishment Global (BRE Global England). BREEAM rewards organizations with award points or 'credits' if the performance of the building is above regulation. Buildings are assessed through nine areas: energy, management, health and well-being, transport, water consumption and efficiency, materials, waste, pollution, and ecology and land use. The overall accumulated credits are translated into the following scales: pass, good, very good, excellent and outstanding (where outstanding is the highest). BREEAM is now the most used environmental evaluation method, with already 200.000 buildings certified and over a million registered for certification in 2011 (BRE Group, 2011). The tool is adapted for every country, to stay close to the legislation and building styles of that specific country. At this moment some versions exist, being BREEAM-UK, BREEAM-NL, BREEAM-ES, BREEAMNOR, and BREEAM-DE. For nations without their version, BREEAM International is used (DGBC, 2013).⁴⁸

⁴⁷ (Kats, 2003)

⁴⁸ (Nadine Wessels, 2014)

3.7 Advantages of sustainable building

As mentioned earlier organizations are integrating the concepts of sustainability not only due to pressures from society, or from a humanitarian standpoint, but also because it has shown to have multiple advantages and can even generate economic value (Holliday, 2001). Sustainable buildings can foster numerous advantages for parties in the real estate sector and end users, ranging from improved health of occupants to economic benefits.⁴⁹

The environmental benefits of sustainable buildings are already firmly supported (Heerwagen, 2000; WGBC, 2013a; Zuo and YuZhao, 2014). However, sustainable buildings also bring attractive financial and strategic benefits.

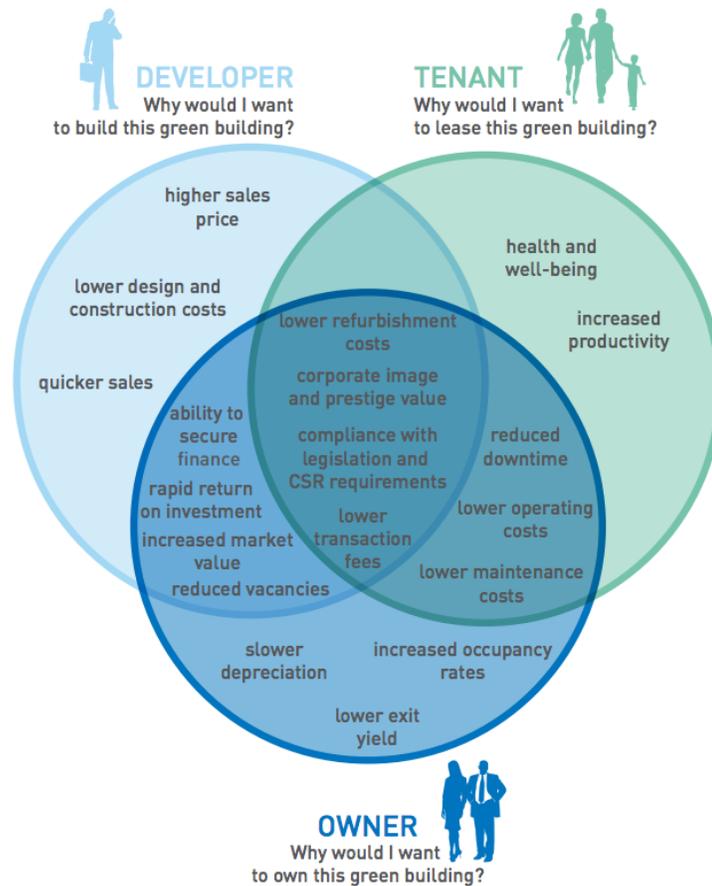


Figure 8. Why green building.⁵⁰

⁴⁹ (Nadine Wessels, 2014)

⁵⁰ (WGBC, 2012)

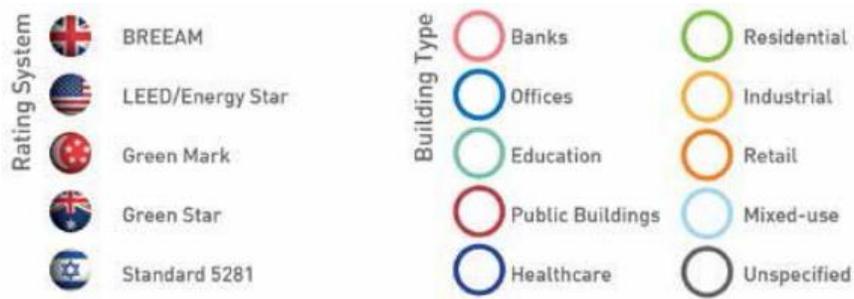


Figure 10. Cost premiums sustainable building⁵³

Indeed, increase in cost premiums can be commensurate to the increased level of sustainability aspirations and certification. For example, a zero carbon building shows a 12,5% cost premium as compared to a conventional building.

However, for the majority of certified buildings, the cost premium mostly ranges from less than 0% to 4%. Multiple studies show that sustainable buildings do not necessarily require higher investments, in fact, there are cases where sustainable buildings need fewer investments (WGBC, 2013a). Higher levels of certification will lead to a higher cost premium. In the research of Kats (2003) among 60 LEED-certified buildings it illustrated that depending on the level of certification (Certified, Silver, Gold or Platinum), the cost premiums range from 0,66 with LEEDCertified, till 6,5% for LEED-Platinum. On average, higher levels of certification will lead to a 0% to 10% cost premium, while the highest levels of certification range from 2% to 12.5% cost premium (WGBC, 2013a).

Even though multiple reports show that sustainable buildings do not necessarily lead to extra cost, many professionals in the construction industry are still under the impression that sustainable buildings increase the design and construction costs (Ambec and Lanoie, 2008; Kats, 2003). Professionals estimated the extra cost for a sustainable building between 10-20% and sometimes even 29% which could be due to relying on old data, or a lack of knowledge that prices are decreasing. Another reason can be that they saw showpiece buildings with additional costly finishes that may not be financially viable.

⁵³ (WGBC, 2013)

This perception continues to present a challenge for the construction industry (WGBC, 2013a).⁵⁴

3.7.2 Asset value

Sustainable buildings are inclined to have higher asset values than conventional buildings. This difference in asset value is evidenced by higher selling prices, which are related to some benefits being: higher rental/lease rates, lower operating expenses, higher occupancy rates and lower yields (WGBC, 2013a). The research of Miller (2008) among 643 Energy Star- rated buildings and 2000 control buildings shows that buildings which are Energy Star rated enjoy higher occupancy rates, higher rental rates, and higher sales prices. These figures are depicted in the chart below. Moreover, in another research by Eichholtz et al. (2009a) 10.000 commercial buildings were investigated, divided into LEED-Certified, Energy Star labeled and control buildings. The study discovered that Energy Star labeled buildings will rent for 3% higher per square foot. Premiums for effective rent are even higher, being 6%. Moreover, the purchasing prices of sustainable buildings are on average 16% higher than compared to the control buildings, and the occupancy rate is slightly higher. Research of USGBC (2012) shows other results, in this research the building value of sustainable buildings are 10,9% higher for new constructions and 6,8% higher for existing buildings. Also, they discovered an increase in the occupancy rate of 6,4% for new developments and 2,5% for existing buildings. Conversely, it can also be expected that organizations who fail to amend the sustainability performance of their buildings will not get a 'green' premium, but a 'brown' discount (Miller, 2008). As a result, the real estate sector is beginning to think about innovative solutions to ensure the value of their assets (AgentschapNL, 2010).⁵⁵

3.7.3 The expenses of operating

Sustainable buildings cost less to operate and maintain. In the research of Kats (2003), Rashid et al. (2012) and Watson (2009) it showed that sustainable buildings use between 25 - 30% less energy as compared to traditional buildings. There are also examples of reduction in energy use by 42% (Lockwood, 2006) and even 50%.⁵⁶ In new

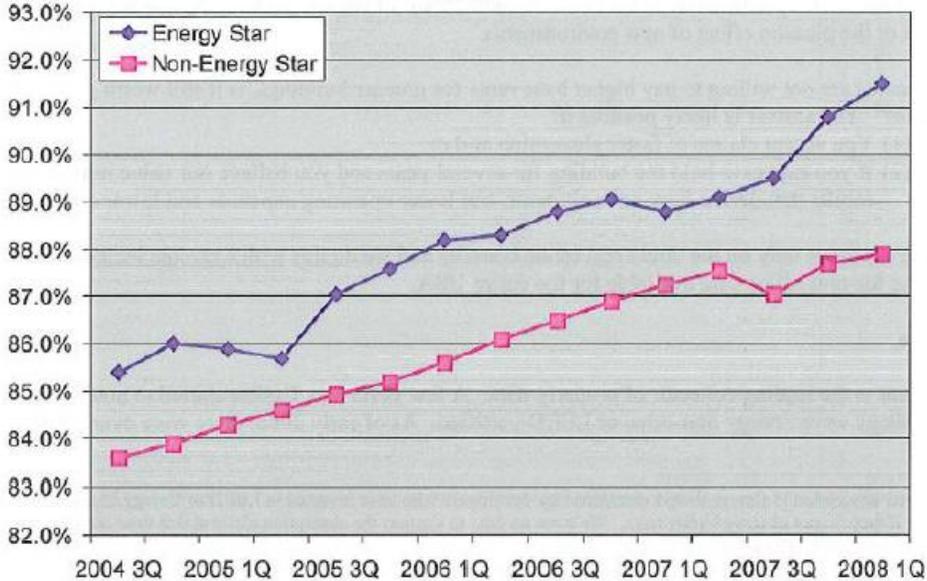
⁵⁴ (Nadine Wessels, 2014)

⁵⁵ (Nadine Wessels, 2014)

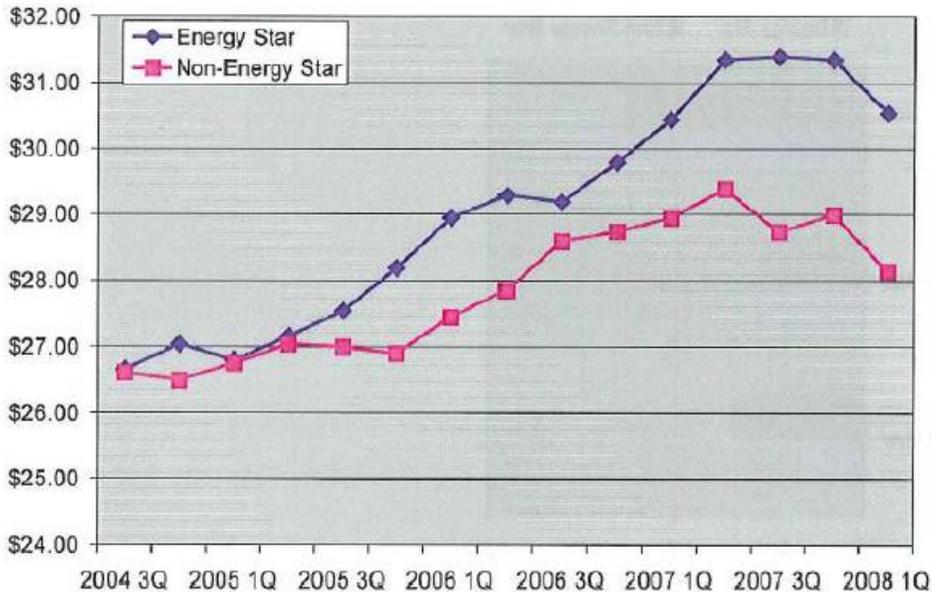
⁵⁶ (Robichaud, L.B., & Anantatmula, 2010)

constructions, the energy savings are the highest, but also for refurbished existing buildings the energy savings can be substantial. Miert et al. (2012) discovered that the Netherlands renovated energy efficient buildings use up to 40% less power compared to conventional buildings.

Occupancy rates Energy Star- rated building versus control buildings



Direct rental rates Energy Star- rated buildings versus control buildings



Sales prices Energy Star- rated buildings versus control buildings

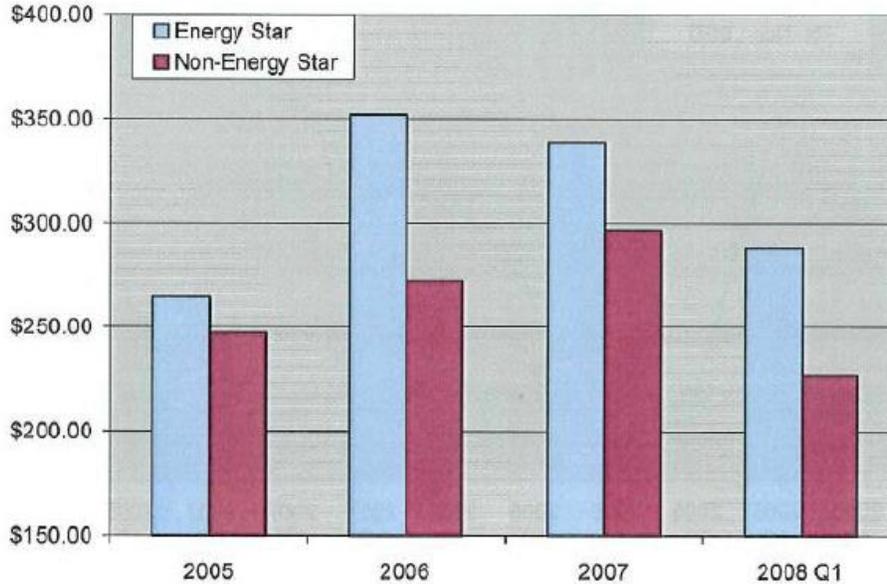


Figure 11. Occupancy rates, rental costs, and sales prices⁵⁷

Another primary benefit is reducing water consumption. Already in 1996, Gottfried discovered that water conservation and efficiency through a sustainable building could lead to a substantial reduction of water usage in buildings. Further, changes in irrigation systems, water efficient appliances, and behavioral awareness can reduce the water consumption by about 30% (Gottfried, 1996). Kats (2010) estimates that the water consumption savings that can be accomplished are 39% over that of a conventional building. Another beneficial part of saving water is that it results in the reduction of GHG emissions, mainly CO₂ and a reduction of waste production (Fernanda Rodrigues et al., 2012). Energy and water savings are the main contributors to the decrease in operating expenses, but there are also other examples. Such as up to 13% fewer maintenance costs due to low-maintenance appliances (Rashid et al., 2012), fewer insurance claims due to a decrease in accidents from materials below standards, less need for pest control (Gottfried, 1996) and less frequent replacement cycles through cradle-to-cradle approach (WGBC, 2013a). From a lifecycle point of view, a saving which is consequent of an investment in the sustainable design and construction of buildings can overstep

⁵⁷ (Robichaud, L.B., & Anantatmula, 2010)

any extra investment costs substantially. With a minimal upfront investment of a 2% premium, a structure can yield savings over ten times the investment (Kats, 2003). Thus, if for example one billion euro's is invested in sustainable buildings, this will yield a saving of ten billion euros.⁵⁸

3.7.4 Productivity, health and well-being

According to Kats (2003) and WGBC (2013a), the effect of health and productivity expresses itself in the far-reaching costs of employees, considering that the cost of labor is considerably higher (85%) than the prices for rent (10%) or energy (1%). Therefore, even small improvements in employees' health and productivity can produce considerable financial benefits. One of the driving forces behind the appearance of sustainable buildings is creating a desirable indoor environmental quality, which promotes health, comfort, productivity and employee satisfaction. Attributes that increase the indoor ecological quality include high levels of natural daylight (Reinhart and Fitz, 2006), artificial lighting that increases lighting quality and decreases computer glare (Hirning et al., 2014; Rashid et al., 2012), increased contact with the natural environment (Brown et al., 2010), advanced ventilation systems that improve airflow and reduce indoor pollutants (Singh et al., 2010; Heerwagen, 2000), thermal comfort and inviting workspaces (Brown et al., 2010).

Sustainable buildings with a desirable indoor environmental quality can contribute to the health and wellbeing of the users, which results in increased productivity and therefore, a better business result (Ajala, 2012; Heerwagen, 2000; Kats et al., 2003). While more report is needed, based on the existing studies, it can be concluded that a better environmental indoor quality will result in healthier, more productive and more comfortable employees (Singh et al., 2010).

Moreover, sustainable buildings can also have a positive effect on the sense of pride of employees towards the organization. In 2011, Tim Hortons (fast food chain) investigated their organization. Sustainability plays an essential role in this organization, and the

⁵⁸ (Nadine Wessels, 2014)

results show that 97% of the members are proud to work for this organization (Tim Hortons, 2011).

3.7.5 Image of the organization

The reputation of an organization is distinguished by its solvency, its trustworthiness, and its social responsibility. Considering that sustainability is a component of social responsibility, it can thereby contribute to the image of an organization (Eichholtz et al., 2009b). For example, if an organization reduces its energy use, they consequently mitigate their GHG emissions and therefore the environmental impact. The field is increasingly noticing this. Moreover, a sustainable building can contribute to the attraction and preservation of outstanding employees and thereby improve the competitive advantage of the organization. A sustainable building can also help improve an environmentally unfriendly image. The building can then perform as a figurehead (Hartogh, 2011).

3.8 The current and future state of the sustainable buildings

3.8.1 Sustainable building in the real estate sector

The number of sustainable buildings is increasing around the world. Sustainable building is no longer only driven by idealism; it is now seen as a business opportunity through the above-stated benefits (Kibert, 2004). By looking at the real estate sector, different researches indicate that the added value of the sustainable buildings is getting visible in the real estate sector. Noticeable is that this trend is not confined to specific parts of the world or particular economies (McGraw-Hill Construction, 2013). According to RREEF Research (2008), several factors influence the increased attention for sustainable buildings globally being tenant requirements, government regulations, and demands for socially responsible investments. These effects are driving a rapid transformation to sustainable buildings, and this is visible by the explosion in the numbers of sustainable buildings that are being developed. In the United States sustainable building is becoming standardized among AEC firms, consultants, and owners. In 2012, 40% of the respondents stated that they are involved in high levels of sustainability, and this number is anticipated to grow to 53% in 2015 (McGraw-Hill Construction, 2013). Blumberg (2012) confirms the increasing interest for sustainable buildings. Therefore, the demand for

constructing sustainable buildings is increasing very fast, and consequently, the real estate sector is more willing to make their buildings more sustainable.⁵⁹

Even though this research shows positive results for the future of sustainable buildings, it has to be recognized that the current state of sustainable buildings in the real estate construction sector is still depressing (Blumberg, 2012). The most significant limitations for sustainable buildings in the real estate sector are always the issue with costs and the potential that sustainable investments are not financially viable. Also, there is a lack of knowledge of the impact of exhausting natural resources (WGBC, 2013a). Fortunately, an upward trend is visible, and it appears to be that the real estate sector is becoming increasingly aware of the many advantages of sustainable buildings, especially regarding new constructions. However, the stock of the existing office space in the U.S. dramatically outnumbers the new office stock that is being developed each year. Therefore, existing buildings have the enormous potential to significantly improve the sustainability performance of the built environment (Blumberg, 2012).

However, sustainable building is growing around the world. It has become a manner in which organizations increasingly address the sustainability performance of buildings in the design, construction, and renovation of buildings. Sustainable building is no longer only driven by idealism; it is increasingly being seen as a business opportunity (Kibert, 2004). By looking at the real estate sector, different researches demonstrate that the added value of the sustainable building is getting more in the real estate sector. For example, in the research of McGraw-Hill Construction (2013) among AEC organizations (architects, engineers, and contractors), consultants and owners from 62 countries, it showed that 94% of the respondent's report using some sustainability feature in their building. By 2015 over 50% of these organizations expect to be at a high level of the sustainable building, which means that more than 60% of their building operations are sustainable and it is an 82% increase as compared to 2012. Remarkable is that this trend is not confined to specific parts of the world or particular economies. In each of the 62 assessed countries, sustainable building features are increasingly being used, though at different rates. According to RREEF Research (2008), several factors influence the

⁵⁹ (Nadine Wessels, 2014)

increased attention for sustainable building globally being tenant requirements, government regulations, and demands for socially-responsible investments. These factors are driving a rapid transformation to sustainable building, and this is visible by the explosion in the numbers of sustainable buildings that are being developed. In the United States sustainable building is becoming standardized among AEC firms, consultants, and owners. In 2012 40% of the respondents stated that they are involved in high levels of sustainability, and this number is expected to grow to 53% in 2015 (McGraw-Hill Construction, 2013). Blumberg (2012) confirms the increasing attention for sustainable building.

According to Blumberg, the demand for sustainable buildings is increasing very fast. Consequently, parties in the real estate sector are more willing to make their buildings more sustainable. Moreover, PWC (2013) discovered that the real estate sector is increasingly seeking opportunities to increase their energy efficiency and implement sustainability features in their buildings.

Even though this research illustrates positive results for the future of the sustainable building, there has to be identified that the current state of the sustainable real estate construction sector is still depressing (Blumberg, 2012). The most significant constraints for sustainable building in the real estate sector are still the matter with costs and the potential that sustainable investments are not financially viable, and the lack of awareness of the impact of exhausting natural resources (WGBC, 2013a). Luckily, an upward trend is visible, and it appears to be that the real estate sector is becoming more and more aware of the many advantages of sustainable building, especially regarding new constructions. However, the stock of the existing office space in the U.S. dramatically outnumbers the new office stock that is being developed each year. Compared to 34 million square feet in new construction and significantly renovated office space, the existing buildings have the tremendous potential with over seven billion square feet of commercial office space to dramatically improve the sustainability performance of the built environment (Blumberg, 2012).

3.8.2 Sustainable building among end users

According to global research among 400 organizations about the mindset of end users to sustainable buildings, the year 2007 represented a tipping point in the mentality of end users towards sustainability. 47% of the global respondents indicated that the sustainability performance of their buildings is a critical issue for them. Moreover, another quarter states that the sustainability performance will become a crucial issue within two years (Jones Lang Lasalle, 2007). More recent research of the WGBC (2013b) describes that in Europe the demand among end users is increasing. The number of non-residential projects certified for BREEAM, LEED, and others has tripled between 2011 and the first half of 2013. The demand for certification is the strongest in the office's sector, followed by the industrial sector and the retail industry.

Besides, according to Deloitte (2014), the demand for sustainable buildings among end users all over the world is also visible through the increasing inclusion of sustainability features in their lease agreements. Research also shows that 70% of the respondents are willing to pay more for a sustainable building. 62% states that they are willing to pay a premium between 1- 10% and 8% state that they are tending to spend over a 10% premium for fitting sustainable practices. It seems to be that the market of end users is ready for sustainable buildings. However, the same research also shows that 46% of the respondents feel that sustainable buildings from the supply side are hardly available (Jones Lang Lasalle, 2007).

It appears that there are still constraints present in the real estate sector and end-users worldwide for improving the sustainability performance of their buildings.

3.9 Sustainable buildings in Germany

In Germany, the sustainable quality of buildings is more and more often certified using so-called green building certifications. For buildings to be successfully awarded a label, it is required, among other things, that the various parties involved in the project participate in drawing up the documents as are necessary for certification.

It is indispensable for a successful certification process that the professionals involved have an understanding of the respective Green building requirements and associated documentation requirements.

Accordingly, this standard has been developed because of the growing importance of Green Building certifications in the real estate industry. Planners, contractors, and building owners are more and more often confronted with the requirements of a building certification system.

The purpose of the standard is to provide a training concept which addresses all professionals involved in the planning, construction, and operation of building to be certified.

Qualification in the field of the respective certification requirements obtained by the training concept presented in the standard is intended to improve, among other things, communication, participation and the calculation of the services required and to reduce problems arising in the course of certification. (RICHTLINIEN, 2017)

The training concept covers the four Green Building certification systems currently particularly relevant in Germany: BNB, BREEAM, DGNB, and LEED. (RICHTLINIEN, 2017)

3.9.1 Guideline for Sustainable Buildings in Germany

The Guideline for Sustainable Building was established by the German Federal Office for Building and Regional Planning to perform integrated principles for sustainable planning, construction operation, maintenance, and use into federal buildings and landholdings. Also, the guideline provides recommendations for the following principles applied throughout the life cycle of the building, which can improve the building's sustainability. (Federal institute for research on building, 2001)

- decreasing the energy demand and the consumption of operating materials
- utilizing the reusable or recyclable building products and materials
- the extension of the lifecycle of products and buildings
- the return of materials to the natural cycle without risk

•Comprehensive protection of natural areas and use of all possibilities for space-saving construction.⁶⁰

Likewise, the guideline provides a preliminary building sustainability assessment procedure for ecological, economic, and social aspects of sustainable building design. Besides, the guideline advocates addressing all three areas to gain a complete sustainability rating. Building assessments are made for various listed criteria in the guideline either qualitatively or quantitatively. The qualitative assessments are evaluated based on the following scale. (Federal institute for research on building, 2001)

1. +=adequate,
2. ++ = good,
3. ++ + = very good,
4. -= poor,
5. ---=inadequate,
6. •= no information.

Furthermore, these assessments are made against the design value or performance of the sustainable building to the guideline value, which represents the minimum value to be achieved. This guideline value can be based on current standards and codes in practice or from recommendations in the Guidelines for Sustainable Buildings. Quantitatively, the assessment is rated (Federal Office for Building and Regional Planning 2001) as:

- Yes=target value reached
- No=target value not reached

However, the Guideline for Sustainable Buildings is compared to the other international sustainable design programs and procedures following the methodology's life cycle analysis procedure. (Bundesministerium für Verkehr, n.d.)

⁶⁰ (Bunz, R.; Henze, P.; Tiller, K., 2006)

3.9.2 German Sustainable Building Council (DGNB)

The German Sustainable Building Council (DGNB – Deutsche Gesellschaft für Nachhaltiges Bauen e.V.) was established in 2007 by 16 initiators from different subject areas within the construction and real-estate sectors. The objective was to promote sustainable and economically efficient building even more strongly in future.

The reaction to the founding of the DGNB was extremely positive. Besides, by the beginning of 2008, 121 organizations had already joined the DGNB. Today the association has more than 1,200 members throughout the entire world because the council considers itself as a German and international knowledge platform. Consequently, the members represent the whole value chain of the construction and real estate sectors such as architects, planners, the construction industry, investors, and scientists bring their comprehensive know-how into the DGNB.

The table below illustrates the different criteria in the building.

criteria		criteria	
ENV1.1	Life Cycle Assessment	SOC1.7	Safety and Security
ENV1.2	Local Environmental Impact	TEC1.1	Fire Prevention
ENV2.1	Life Cycle Assessment - Primary Energy	TEC1.2	Noise Protection
ENV2.2	Drinking Water Demand and Wastewater Volume	TEC1.4	Adaptability of Technical Systems
ECO1.1	Building-Related Life-Cycle Costs	TEC1.9	Sound Emissions
ECO2.1	Flexibility and Adaptability	PRO1.4	Sustainability Aspects in Tender Phase
SOC1.1	Thermal Comfort	PRO2.1	Environmental Impact of Construction
SOC1.2	Indoor Air Quality	PRO2.2	Construction Quality Assurance
SOC1.5	User Control	PRO2.3	Systematic Commissioning

Figure 12. DGNB-System: building equipment related criteria⁶¹

⁶¹ (Bunz, R.; Henze, P.; Tiller, K., 2006)

4. Analysis of existing case studies

The aim is to analyze the two existing case studies of non-residential sustainable buildings and compare them with the case study in Iran.

4.1 Case study1: The Library



Figure 13. Photo of the library building⁶²

Project information:

The project was done for the city council of Christchurch

Site location: Colombo Street, Christchurch

The total floor area is 2400 square meter

Cost per square meter: \$2494

Conventional cost/m2: \$2384

Contract value: \$4.6 m

⁶² (Manatū Mō Te Taiao, 2005)

Annual energy cost savings: 7.5 \$/m2

Annual water cost savings: 0 \$/m2

4.1.1 Economic

The expressive economics for this sustainable building is shown in the following table. Besides, the method of water consumption payment in the city leads the team to consider not the water saving consumption. Therefore, the water saving does not have any payback. However, if the water supplies would be under pressure, this situation maybe would change in the future.

Type of the building	Benchmark capital cost \$/m2	Capital cost \$/m2	Cost premium \$/m2	Cost premium %	Energy saving \$/m2	Water saving \$/m2	Total saving \$/m2	Simple payback years
library	2384	2494	110	4.41	7.5	0	7.5	14.67

Table 2. Cost-benefit summary of the sustainable office building⁶³

Further, combining a remarkable number of environmentally preferred materials, components and technologies in the building also has no straight payback but was done for less than 1% of the total construction costs. Also, considering these factors, along with the fact that this type of building is less drastically serviced and also it makes sustainable building a medium to long-term investment.⁶⁴

4.1.2 Environmental Summary

Energy used - 120 kWh/m2.

- Annual energy cost savings 7.5 \$/m2
- Annual water cost savings 0.0 \$/m2

Water consumption:

- Low pressure and low flow taps
- Collecting the rainwater

Rainwater:

- The features to keep and filter the water from the rain

⁶³ (Manatū Mō Te Taiao, 2005)

⁶⁴ (Manatū Mō Te Taiao, 2005)

Strategies of the site:

- Preservation of existing trees
- The use of local species

Material which is used in the project:

- Low-impact materials

The strategy for waste:

- On-site waste management
- Reusing the components

4.1.3 Client motivation

The client wanted to process a library building that mainly focuses on the lower community of the city. Therefore, a comprehensive community consultation process developed the building design.

Meanwhile, the objective is to be compassionate to the residential character of the area and maintaining a public vicinity simultaneously. Also, an essential purpose of the brief was also to face the policies of the council on energy consumption, and environmental sustainability.

4.1.4 Facilities of the project

The building has three vital functions such as a public library, an education center, and the vernacular service center and attorney office. In the meantime, the building provides some other public facilities such as several meeting rooms, a conference room, and offices for the staff.

4.1.5 Site

There is an existing building which is occupying by the city council and the department of water services. In the meantime, the rest is an open area.

There is a considerable amount of big trees and bushes as well as open areas. Also, there are several aquifer, the stations for locating the pumps, and other facilities. The site is limited by the terrace and the river in the north part.

4.1.6 Concept of the project

The building is not too much high, and it is a single-story building in keeping with the residential nature of the site. Besides, the building has a dramatic saw-tooth form and a stepped plan sitting in a water-filled moat to create a notable appearance.

Also, the site was without any building because the buildings were demolished, but the trees were retained. The aim is creating a park for the people. In the meantime, a part of a plot will be closed, the way to the north and the park will develop to the side of the river.

Afterward, the building is severely insulated to the south where backyard facilities are located. However, this part opens up to the park in the north. People get in the building from the south, and they lead to the public spaces in the north which has quite good landscape and view.

The sawtooth shape roof which is built from breaks has several benefits. Also, the building now has four different blocks. Moreover, the benefit of the roof is allowing the daylight and natural ventilation to come inside the building.

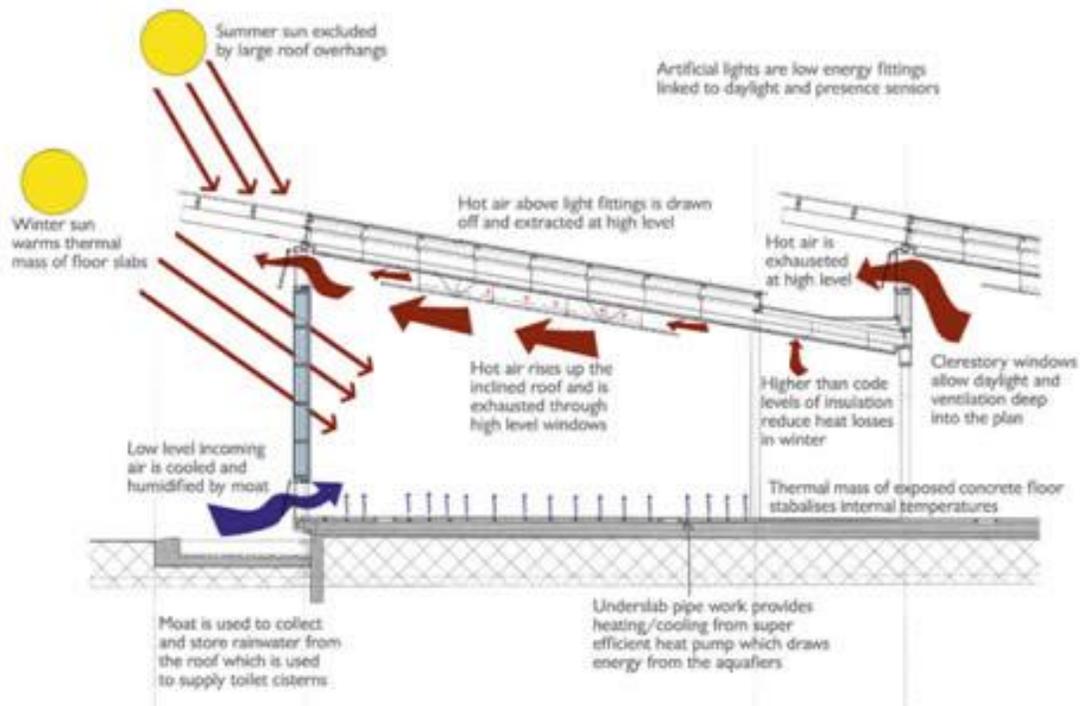


Figure 14. Saw-tooth roof form⁶⁵

⁶⁵ (Manatū Mō Te Taiao, 2005)

Some information about the figure

- The large roof will omit the summer sun
- The thermal mass of the slabs of the floor will be warm by the sun.
- Artificial lights are low energy fixtures and switches which are linked to the daylight with the sensors.
- The rainwater will be collected and kept from the top of the roof to use for the toilets
- The incoming air, which is low pressure, is cooled and humidified by a moat.
- The windows let the daylight come inside, and ventilate the building.
- Hot air rises up and eventually goes out through the windows.
- Hot air of the light switches and fixtures is extracted.
- Hot air is exhausted.
- Under-slab pipes provide heating or cooling from the heat pump which extracts the energy from the aquifers.
- Internal temperature is stabilized by the thermal mass of the exposed concrete.
- Higher than code levels of insulation reduce heat losses in winter.

4.1.7 Energy consumption

The followings occur in low energy consumption:

- double glazed windows which are higher than the code of insulation levels
- facing the north glazing, and large roof combined with existing old trees to improve solar energy
- daylight and ventilation in the whole building due to the roof with the shape of the sawtooth
- improved orientation for solar design with north facing glazed public areas and south facing well-insulated support spaces
- the 3D energy modeling is used to optimize the ratios of walls and windows
- using 3D energy modeling to determine the strategic placement of thermal mass
- a significant number of windows in the whole building.

These strategies were covered with the following procedures to minimize energy consumption:

- aquifer water in the main supply pipes of the city is used as the source of energy for a heating and cooling system
- heating and cooling of the slab
- the windows are opened with the motors to optimize the use of natural ventilation and the use of free cooling
- low-energy T5 light fixtures on shared ballasts linked to the sensors of daylight
- air conditioning in crowded rooms only, connected to presence sensors and contact switches on manual windows to make sure the system switches are off when there is no need.

However, low energy design solutions are strictly checked with 3D energy modeling to ensure they met the payback criteria of the client, which was five years for equipment, but longer for double glazing and insulations.

4.1.8 Water consumption

Reducing water consumption was not a high priority. However, some innovative techniques were assigned to reduce water consumption and minimize the volume of sewage leaving the site. Low flow fixtures are defined in the building as below:

- dual-flush 3/6-liter toilet cisterns
- the urinals without water
- the low flow showerheads
- using the taps with low flow, and automatically turn off

Further, the water around the building fills the moat. The aim is to collect and hold the rainwater to use for the toilets.

4.1.9 Waste reduction

Waste minimization was necessary for the project:

- The target is to have the building without any waste in materials and components in implementation. Also, the waste management strategies adopted to monitor and control the contents during the construction.
- Using renewable materials is the goal of the project to save the environment and optimize the sustainability.

- Using the renewable material and components from the previous buildings under the new building.
- Products with a high recycled waste component such as ceiling tiles, cement, insulation, carpet, and furniture
- Space was dedicated for the gathering and separating the renewable waste.

4.1.10 Materials of the project

The designers decided to select environmentally preferable materials due to the limitations of the budget. These materials are included:

- sustainable timbers
- alternatives to CCA and LOSP timber treatments
- water-based paint systems endorsed by the environmental choice labeling scheme
- acoustic insulation made by wool
- a flexible sheet for the floors
- specific ceramic tiles for thermal mass and durability for a crowded area
- carpet systems which created from recycled materials
- external surfaces are durable, and no need of surface finishes such as stone, glass, and aluminum
- renewable materials
- CFC and HCFC free polystyrene sheet insulation and pipe lagging
- low emission materials, water-based paints, specific MDF, particular plywood, low emission tiles for the ceiling, low toxicity, and avoidance of flexible PVC floor coverings.

4.1.11 Site Specifics

The site specifics are as below:

- The aim was to keep the existing old trees as possible.
- Some trees in the car parking are an exception; the new landscape consists of individual native plants
- The landscape does not need any irrigation after the first establishment.

- Rainwater of the rooftop is collected from the three blocks, and harvested in the moat which is surrounded the building.
- Rooftop rainwater from the back block runs into a Riverstone and a gravel filter. Then, the water runs into the rain garden.
- The stormwater in the car parking is channeled into a landscaped drainage swale for filtering.

4.1.12 Transportation

The car parking has the space for 70 cars that are often full. However, the client has the strategy to reduce the use of vehicles by:

- locating the facility in a suburban center
- bus stops near the entrance of the library
- providing bicycles for the staff
- giving the shower and locker facilities to encourage the people to use public transportation
- the policy is to do not allocate parking for the employee.

4.1.13 Process

Individual changes to the normal procurement process were vital to the environmental success of the project:

- a design brief that clearly demanded that environmentally sustainable development be a priority of the design
- a pragmatic energy brief and a separate energy cost to pay for low energy strategies with approved payback periods
- 3D energy modeling is fundamental
- an interview process which stressed the significance of the ecologically sustainable development
- a design team and project management committed to making an effort to try new techniques
- an intelligent client and specific input at crucial dates from the target of the city council

- a contractor who purchase the best for the project
- a shopping list of energy saving and ecologically sustainable development options, which let the client accept the adoption of particular environmentally sustainable development strategies based on importance, cost, and payback.

4.1.14 Rating tools in New Zealand

In New Zealand, the New Zealand Green Building Council has several assessment tools for different types of buildings. One of these rating tools is Green Star which is using for commercial buildings such as offices, educational and industrials buildings. In the meantime, the New Zealand Green Building Council develops other projects which do not fit the mentioned buildings such as hospitals and theaters.

This rating tools have nine different classifications, with the ranges between 4(New Zealand excellence) to 6(world leadership).

4.2 Case study2: The High school

Project information:

The project is done for the Ministry of Education

The location of the site: Appleby Road, Albany, North Shore

The total floor area is 8,633 square meter

Cost: 2570 dollars per square meter

Conventional cost: 2430 dollars per square meter

Contract value: 22.2 million dollars



Figure 15. High school building⁶⁶

⁶⁶ (Manatū Mō Te Taiao, 2005)

4.2.1 Economic

The table below shows the indicative economics for the case study building. Besides, the savings over the benchmark suggest that the benchmark may be increasing due to more extended operating hours and community use. Also, the intensity of site usage is also increasing. For example, the use of two-story buildings and the enhancing use of computers.

Type of the building	Benchmark capital cost \$/m2	Capital cost \$/m2	Cost premium \$/m2	Cost premium %	Energy saving \$/m2	Water saving \$/m2	Total saving \$/m2	Simple payback years
High school	2430	2570	140	5.45	7.5	0.6	8.1	17.28

Table 3. Cost-benefit of the sustainable office building⁶⁷

4.2.2 Environmental brief

The building has the following measures to optimize the environmental issues. Besides, positive social and economic outcomes are the other measures.

- the annual energy cost savings is 7.5 dollars per square meter
- the annual water cost savings is 0.6 dollars per square meter
- building orientation and solar design
- optimization of windows and walls ratios and thermally efficient glazing systems to improve a high level of daylight and energy efficiency
- the central atrium is designed to the administration building to boost the level of daylight as well as natural ventilation
- lighting systems with high energy efficiency and daylight control
- façade designing with high performance and energy efficiency
- the level of insulation is higher than New Zealand Building Code requirements
- use of ventilation systems to improve indoor air quality and energy efficiency in whole building
- heating system, which is energy efficient and high performance, to prepare the hot water for changing room of the sport center

⁶⁷ (Manatū Mō Te Taiao, 2005)

- collecting and reusing the stormwater.

4.2.3 Project description

The building is located in the Albany area. Also, the school is a new concept for the ministry of education. Moreover, it is established around concepts of 'integrated learning,' the coeducational school provides facilities for students of different levels. Thus, the first stage of the development is configured for 780 students. Meanwhile, in the second stage, the number will increase up to 1400.

Therefore, stage one includes three classroom buildings, an administration office, sports center, and an art center. Therefore, the future stage, second development, will have two more classroom buildings. Also, all of the buildings have two stories. Specialist wisdom areas such as visual arts, science, and technology are divided between each of the classroom buildings. Finally, sports fields and hard surface courts have also been provided.

Also, the classroom concept breaks down the scale of the school into distinct and straightforward groups for the students to relate to each classroom group is then broken down into core teaching areas, instructing areas, communication space, resource and office areas.

However, the design team of the project was gathered together the experiences of the design of the first two secondary schools to be developed by the ministry of education in 25 years (Botany Downs Secondary College and Alfriston College both completed in 2004) as well as the experiences of the establishment board.

Eventually, a significant factor in the design of the school's built environment was the consideration of environmentally sustainable development measures, mainly to improve positive educational outcomes, to improve teaching and learning environments, to minimize the energy consumption and to reduce environmental impact.



Figure 16. Some photos of the building⁶⁸

4.2.4 Energy Efficiency

- Insulation of the roofs and walls, which are higher than the building code levels of the country, reduce heating energy consumption.
- High performance double glazed windows to reduce heat loss in winter.
- Underfloor insulation improves the performance of the atrium with the underfloor heating system.

⁶⁸ (Manatū Mō Te Taiao, 2005)

- Passive solar design techniques make the best use of the area to improve daylight levels and reduce the energy consumption.
- Daylight sensors reduced energy consumption.
- Efficiency in lighting according to the occupancy of the room
- A ventilation system provides natural air.
- The air ventilation systems are able the classrooms to use air exchanger to preheat outdoor air and reduce heating energy consumption in winter.
- The air conditioning unit serving the art center supplies full fresh air to space for improved indoor air quality. In the meantime, an air exchanger recovers the heat or fresh air to minimize energy consumption.

4.2.5 Supply

- A condensing boiler improves the energy generation efficiency of the central gas-fired heating system.
- Wider temperature differentials in the heating system reduce pipe and pump sizes and keep down capital and running costs.

4.2.6 Green energy

- Solar panels on the roof of the building heat the water before the consumption in the changing rooms.
- The student center atrium roof is oriented to allow for the future providing solar panels. The location at the front of the site will allow a visible and iconic architectural form to educate users and the public.

4.2.7 Targets of the energy consumption

- The target is to have an annual energy consumption for the entire site less than 80 kWh/m²/annum. This amount is an average energy consumption for the whole site including offices, classrooms, and IT facilities.

4.2.8 Water

- Surface water is treated in rain gardens and swales strategically located around the site.

- A buried stormwater pipe collects surface water, which is reused for irrigating the sports field, cutting down the use of potable water.
- Rainwater from the three classroom buildings roofs is collected in the tanks. The rainwater is used for toilet flushing and for general irrigation to reduce the use of potable water.
- Low-flow water fixtures are used including taps and showerheads.
- Occupancy sensors are used for demand control of urinal flushing.

4.2.9 Materials and waste

- Construction waste was reduced by changing the façade design. Standard material sizes were used to minimize construction waste.
- The waste management sub-contractor sorted construction waste to minimize landfill. Construction waste was monitored monthly, with reporting provided on tonnage to recycling versus tonnage to landfill.
- Thermal mass is used extensively to regulate internal temperatures to improve thermal comfort and help with passive solar heating in winter, particularly in the atrium.
- Multiplex's project management plan recognized environmental impact reduction strategies.
- The provision was made for on-site filtration and collection of paint and materials including cleaning liquids, which were then disposed of off-site monthly.

4.2.10 Indoor environmental quality

Measures to promote positive indoor environmental quality include:

- window-to-wall ratios to balance solar heat gain, reduce glare and promote high daylight levels
- external shading assessment and shading design
- design of south-lights to the art classrooms to promote daylight levels and natural ventilation
- design of the administration building to promote daylight levels and natural ventilation
- using thermally efficient glazing in some areas

- using thermal mass and insulation to improve thermal comfort
- a mixed-mode (more than one type) ventilation strategy responds to seasonal changes and promotes indoor air quality and energy efficiency
- supplying full outdoor air to the classrooms in winter improves indoor air quality and a healthier learning environment.

4.2.11 Health

- Extensive use is made of natural daylight. The variability of natural daylight levels can also provide more visual stimulation. Spaces that are lit mainly with daylight can have a positive physiological impact, creating better learning environments that encourage increased performance from students and teachers.
- Natural ventilation throughout the school improves indoor air quality.
- Full outdoor air systems with heat recovery are used in winter to promote indoor air quality when windows need to be closed to retain heat or when quiet is required.

4.2.12 Site

Incorporating sustainability into the management and curriculum of the school is possible in some ways and includes waste management, recycling systems, capitalizing on existing land use and ecology, and promoting transportation initiatives that minimize environmental impact.

The school has established an environmental management plan in line with ISO14001. Their 'walk it in, walk it out' policy is particularly interesting. With no rubbish bins, on-site the pupils must take all their rubbish home for disposal and recycling.

4.2.13 Monitoring and results

Only electrical energy use data was available because of discrepancies with the water and gas supply billing.

The monthly electrical energy use is presented in the table below. A gross floor area of 8633m² projects electrical energy use based on current data to be 37.5 kWh/m²/annum. This projection assumes energy use from November 2005 to April 2006 to be the same as that for May 2005.

The electrical energy use data must be tempered by the fact that two of the classroom blocks are currently not being used.

School holidays and an increased role for 2006 will affect the final energy consumption figures.

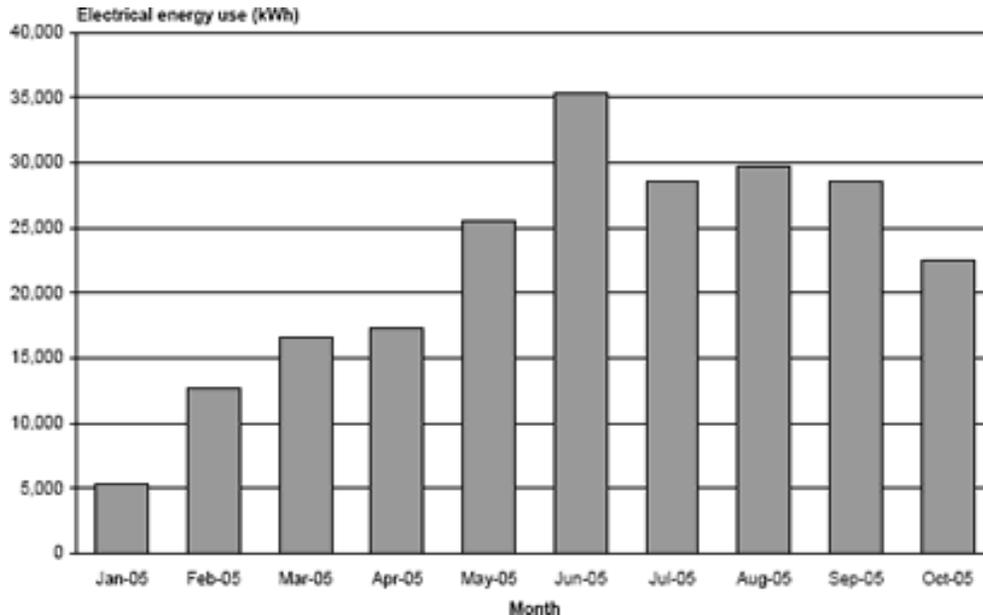


Figure 17. the monthly energy consumption⁶⁹

A conservative assessment obtained by removing the gross floor area of these two classroom buildings from the projected annual energy use results in 62.3 kWh/m²/annum. This projection is less than 80 kWh/m²/annum and does not include gas consumption for primary heating.

Also note however that at 2032 m², classroom A is 621 m² larger than classroom B. This projected energy use is an average of both classroom blocks and offices facilities that typically have very different energy use profiles, which may skew these projections.

Only time can yield more accurate results of annual energy use; however, currently available data looks promising for the first year of school operation with systems still bedding in and buildings being conditioned.

⁶⁹ (Manatū Mō Te Taiao, 2005)

5. Development of the case study in Iran

5.1 Buildings in Iran

Materials used in construction projects of Iran are far from international standards, and because the designer's assumptions are based on the use of standard materials, they are faced various ambiguities at the time of the project which is also unacceptable. Using Miscellaneous iron types, Joists which made in non-standard workshops without the presence and supervision of experienced engineers, the use of nonstandard concrete and thousands of other problems cause poor performance and free of standard projects. In fact, these are the opposite theory of the engineers. Finish works are the next phase of construction projects, existing of non-standardized materials such as pipes, tiles, ceramics, and so on lead to spending a lot of time and money in achieving a seemingly beautiful building, but screwed up. The materials which use in Iran are brick, ceramics, stone, cement and its products, lime, gypsum, metal molds, some kinds of steel and cast iron which are alloys of gross iron which they are considered to be the most precious metal materials, wood and its products, bitumen, glass, paints and coatings decorative, structural plastics.

However, building national regulations as a turning point in the history of civil engineering in Iran has been started by the Ministry of Roads and Urban Development with the participation of the Engineer Community which is responsible for building regulations and the Specialized Committees of Discussions in more than twenty years ago. If building materials follow the standard of agenda 19 in building regulations, some of the energy consumption issues will be solved, but entering to a new generation of buildings which have many differences with conventional buildings is the new topic these days.

In the meantime, Iran Green Building Council is an NGO organization which is not the member of the World Organization of Green Buildings.

5.2 Iran Green Building Council

Although the sustainable building in Iran is not familiar yet, efforts have been made in this regard such as the establishment of the Green Building Council of Iran.

The council is a non-governmental council with the aim of developing and promoting design, construction and use of environment-friendly buildings established in Tehran in 2008 for encouraging the implementation of Green Building Construction Practices. Meanwhile, some activities such as working with the German Green Building Council for specialized meetings have been done. The target of Iran Green Building Council is the development of sustainable and Eco-friendly buildings. The organization is trying to find an expert method to achieve sustainability in the construction industry as well as a national organization for development to provide the tutorials and regulations for sustainability to the users.

5.3 Energy consumption in Iran

A look at energy consumption in Iran and its comparison with the global average make the importance of green building in Iran double. For example, per capita, annual consumption for electricity in Iran is 2500 and in the world is 800 kilowatts which are three times more than the average. Also, the per capita consumption of water daily in Iran is 300 liters and in the world is 150 liters which are two times more than the global average. Per capita annual gas consumption in Iran is 1700, and in the world, it is 600 cubic meters, which is about three times the global average. Energy consumption in Iranian buildings is also about four times the average for European countries.⁷⁰

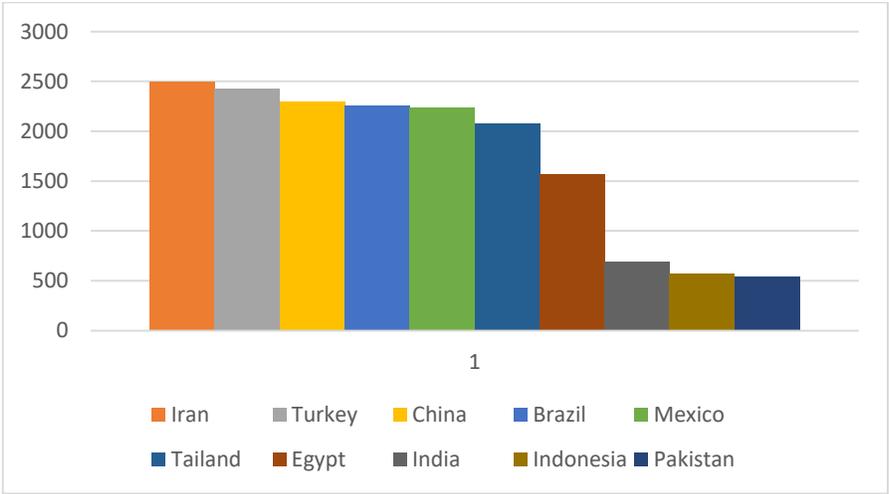


Figure 18. Energy consumption in Iran and other countries⁷¹

⁷⁰ (Danesh Nama, 2013)

⁷¹ (shiraz , 2018)

At the moment the efficiency of central power supply plants in Iran is 30 to 45 percent that means about 65 to 70 percent of fuel consumption fossils are wasted in these power plants. The most important reasons for low energy efficiency in the building sector are as below:

- Lack of specific standards for energy consumption in the building sector
- lack of experiment to monitor the optimization of energy consumption
- Incomplete and incorrect use of new technologies building section
- Observance and non-enforcement of national building regulations in the country
- The low level of technical knowledge of people working in this sector and low awareness of utilizing buildings.

As an example, 21% of energy consumption on the floor of the buildings, 26% in the external walls and 3% in stairwells are wasted. Of course, efforts to improve the quality of buildings are faces such as the energy consumption label which is illustrating the degree of energy as well as providing the degree of thermal comfort of the building.

5.4 Development of the Case study

5.4.1 introduction

The selected building is situated in Mashhad City, which is the second most populous city. The recently constructed office building that was selected is in a relatively new neighborhood which has been developed in recent years.



Figure 19. Location of Iran in the world⁷²

⁷² (kisspng, 2018)



Figure 20. Location of Mashhad City⁷³



Figure 21. Location of the building⁷⁴

It is necessary to consider the climate conditions of the place when performing an analysis on the use of energy and water consumption of a building. Therefore, the climate conditions of Mashhad are as below:

Mashhad has distinctive features of the climate due to the particular geographical location in the border area between the north and south of Khorasan. In the meantime, the interference of different climate fronts is also influencing on it.

Besides, most of the Mashhad-Neyshabour plain is part of a cold and dry climate and part of Mashhad-Quchan Plain Semi-arid and cold. Also, a small part of the highest altitudes of Binalud and Hezar Masjed mountains are part of a cold, and humid climate. Therefore, the city of Mashhad has varied climate, but temperate and temperate with

⁷³ (maps, 2018)

⁷⁴ (maps, 2018)

warm and dry summers and mild or cold winters. Further, winds in the city of Mashhad are more in the direction of the south-east to the northwest.

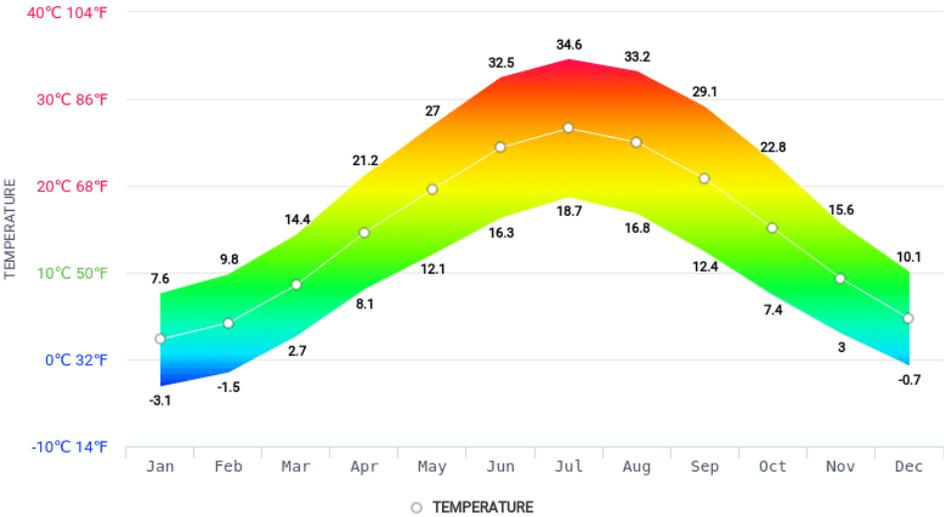


Figure 22. Mashhad temperature⁷⁵

	January	February	March	April	May	June	July	August	September	October	November	December
Day	7°C	9°C	14°C	21°C	27°C	32°C	34°C	33°C	29°C	22°C	15°C	10°C
Night	-3°C	-1°C	2°C	8°C	12°C	16°C	18°C	16°C	12°C	7°C	3°C	0°C

Table 4. Mashhad temperature, day & night⁷⁶



Figure 23. Daylight in Mashhad City⁷⁷

⁷⁵ (Hikersbay, 2018)

⁷⁶ (Hikersbay, 2018)

⁷⁷ (Pazhtavan, 2018)

The average of daylight in Mashhad city has shown in the figure. July has the sunniest hours, 12.27 hours, and November has the lowest sunny hours by 3.8 hours a day. The average of daylight in Mashhad is about 8 hours. The daylight in Mashhad could be an opportunity for sustainable buildings to use the daylight for energy saving.

Moreover, the sustainable office building is situated in Mashhad city with 9000 square meters. Considering the importance of addressing new energies in contemporary architecture and due to the urgent need for optimal energy consumption in current building constructions in Iran, this project aims to create the offices and the improvement of its quality on the one hand and to create a sample for the future buildings on another hand.

The project is an office building which supports the objectives of all businesses. Meanwhile, the building design satisfies the user with the high quality and perfect environment. Creating this kind of buildings encourages the businessmen to buy or rent the office. In the design process, the team developed the building in the way to fulfill the motivation of the owner as well as the new users.

Refer to the interview which has done with the project manager of the project, in the design phase the consultants reviewed the design again. The data showed that the design of the building had a proper result and improvement.

5.4.2 Summary

Project name: Kosar office building

Site address: Mashhad, Iran

Total floor area: 9000m²

Cost/m²: 1160 \$ per square meter

Energy savings in a year: 11 \$/m²

Water saving in a year: 0.3 \$/m²



Figure 24. The office building

5.4.3 Economic

Some features which make the building sustainable was mentioned in this case study. These features are such as double glazed windows with high performance which have too many benefits. The importance of this kind of windows could be considered either in energy consumption or the size of the devices such as air conditioners. Meanwhile, the other features like photovoltaic solar panels for heating the water were not designed for the building because in office buildings the demand for hot water is not too much.

According to the interview with the project manager, the data which has found from the modeling of the energy consumption, it has predicted that the energy cost saving is approximately 14.7 \$ per square meter and with the water consumption saving which has followed the sustainability method, the prediction would be 15 \$ per square meter.

(Manatū Mō Te Taiao, 2005) Indicated that the ecological aspect of sustainable buildings premium is around 5 percent which the simple payback would be less than seven years. Also reported that the return from ecologically sustainable development for office buildings have more benefit for the owners of the building. In office buildings, the amount of money which has increased due to the sustainability should be added to the rent of the office. Therefore, having a more comfortable building increase the productivity which is a benefit as well.

5.4.4 Environment

- Energy consumption 145 Kwh
- Using the rainwater for irrigation and toilets
- 80% of material waste recycled

5.4.5 Concept

The large central place in the floors has designed to gather the staff all together for either refreshing or sharing their information. The lifts are accessible in the building, but the stairs also are useful because the building height is not too much so the people might

want to take the stairs instead of the lifts. The exciting thing in the staircase is the visual connection. Means the people who are on the stairs can see the upper or lower floors.

5.4.6 Facilities

- Car parking
- Bike and motorcycle parking
- Kitchen
- Lockers
- Central printers

5.4.7 Materials

The walls of the building aim to increase the comfortability of the staff and reduce the energy consumption. Also, another exciting feature of this building is the using of natural light during working hours which has a high performance by using the double glazed curtain wall. The advantage of this wall could be accessibility to the daylight as well as the excellent views.



Figure 25. double glazed curtain wall⁷⁸

⁷⁸ (Trimo, 2018)

5.4.8 Water

In this building, the low-pressure taps, low flow, have used to decrease the water consumption. In addition to this, the same system has used for the flushes of the toilets. For irrigation, using the rainwater is another option which has considered in this building. Besides, generally, the consumption of grey water is essential for the sustainable buildings. The process is reusing the water which has consumed in the different parts of the building. After filtering the water, the water will run into the tank on the top of the roof. Afterward, the water is ready again to use it for the toilets, and irrigation.

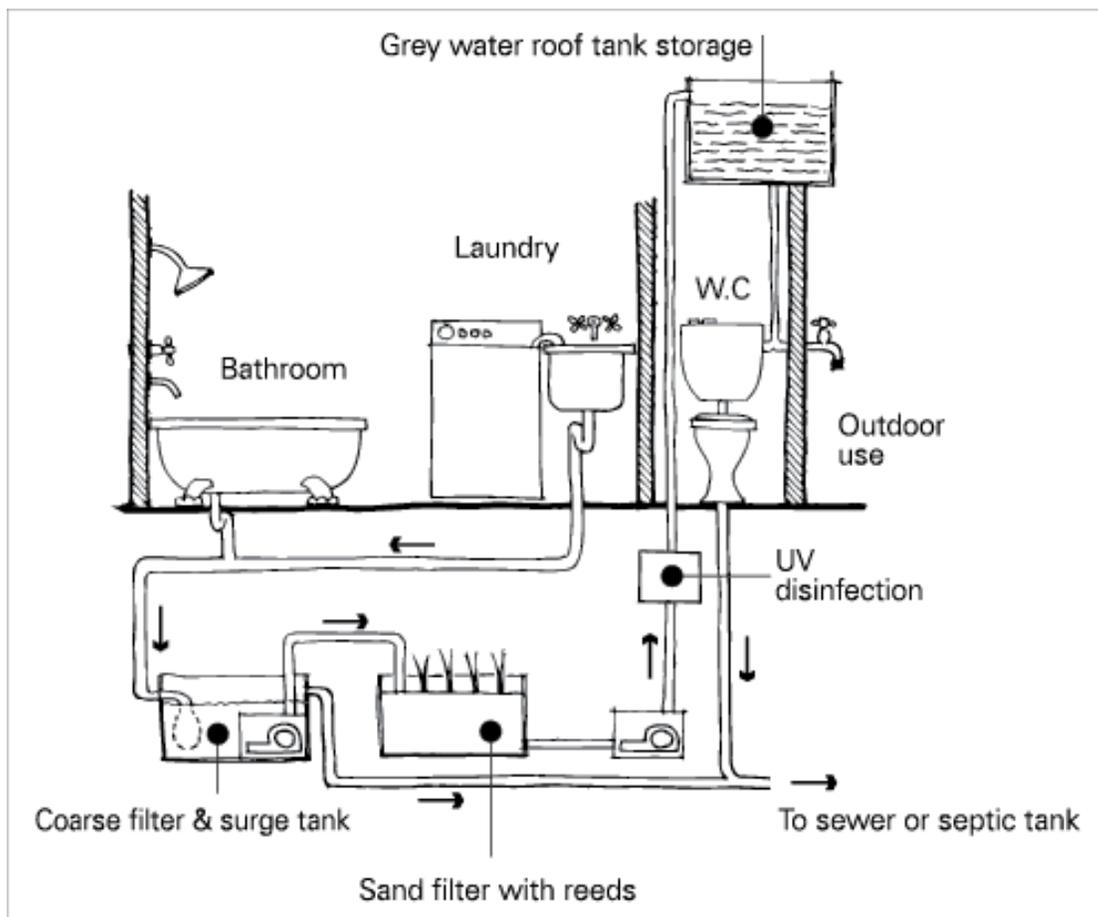


Figure 26. Wastewater reuse⁷⁹

⁷⁹ (Australian Government, 2013)

5.4.9 Energy

The building slogan is high quality and energy efficiency within the environment. According to the present analysis of the building, the energy consumption is 145 kWh per square meter. The target of energy consumption was less in the design phase, but it was not achieved in implementing phase.

The building performance is higher than the benchmark in Iran in term of energy consumption. This amount of energy consumption is very well compared to the other buildings in Iran because as already mentioned the sustainable buildings are still far from the other buildings in different countries.

HVAC system has chosen for the project which is the most suitable one in term of energy reduction and to achieve the aim of the internal environment. The advantage of the system is to control CO₂ and other criteria which will decrease the ventilation fans usage and also the pumps. As a consequence, the energy consumption will be minimized.

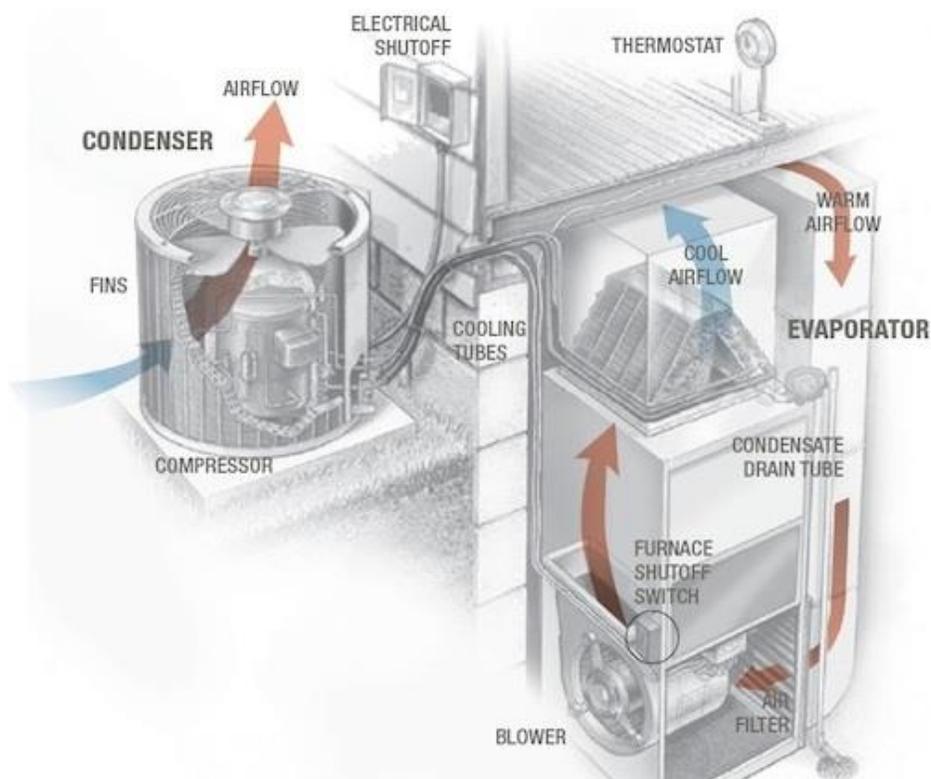


Figure 27. An example of an HVAC system⁸⁰

⁸⁰ (Andersenservices, 2018)

Using the fluorescent has helped the team to reduce the energy consumption. Also, the natural lighting system is another advantage of the building. The project manager mentioned that the lighting power density is 12.5 W per square meter. In the meantime, the sensors control the lighting system in the whole building.

The project has the building management system to monitor and control the building as well as energy consumption. The building management system will identify the area which consumes more energy to be fixed afterward.

The advantages of building management system are as below:

- Controlling the HVAC
- Controlling the lighting system
- Monitoring and controlling the energy
- Electrical distribution
- Renewable energies
- Motor control
- Critic power and cooling
- Access control
- Video security

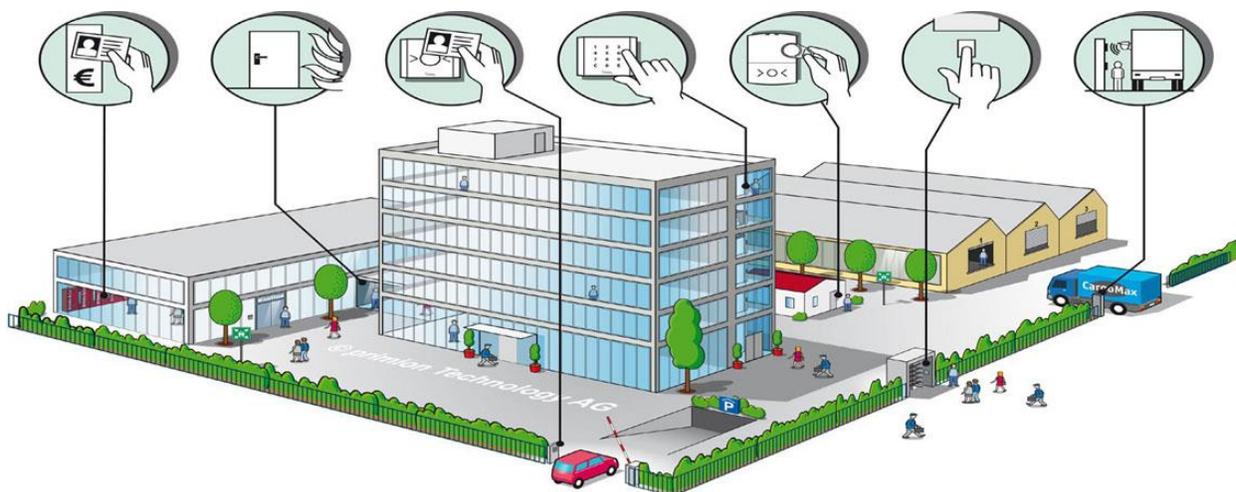


Figure 28. Building management system⁸¹

⁸¹ (Alsadrah, 2018)

5.4.10 The other strategies for energy saving

There are other strategies to reduce the energy as below:

- Fans and pumps have different speeds
- Using the low flow fixtures to reduce the water consumption
- Controlling the usage with sensors
- Using the double glazed curtain wall
- Using natural fresh air for the chiller plant

5.4.11 The features of the sustainable building which have anticipated before the implementing

In the design phase, some features of the sustainable building have anticipated by the team to achieve the goals. These features are as below:

- Ventilation systems for efficient heating and cooling
- Light with optimal energy consumption
- Appliances and plumbing with the least waste
- Building space design to maximize solar energy
- Lowest damage to the canvas and natural habitats
- Alternative electric sources such as wind power or solar energy
- Use of non-toxic and abnormal materials both inside and outside the building
- Use of storage papers from other buildings
- Optimal use of space
- Using natural light

5.4.12 Interview with the project manager of the project⁸²

1. What was the purpose of making this building sustainable?

The protection of energy resources and preventing the loss of natural resources, protecting and reducing environmental damage, preventing the loss of billions of dollars of energy resources, increasing the quality, lifespan of buildings, and ultimately replacing

⁸² (Nourallahi, 2018)

renewable energies with fossil fuels are the goals which were expected to achieve in the design phase.

2. What are the difficulties of sustainable buildings in Iran?

Generally, the existing problems are due to the lack of knowledge in sustainability topic within the planning phase, lack of rules and regulation for urban development, lack of proper regulation in agenda 19 of national regulation for buildings and misleading the technical regulations of Building Envelop.

Furthermore, the owner of the building maybe is not desiring to have a sustainable building because finishing the project with less money and more earning is the owner's motivation in Iran. They believe making the sustainable building cost them more than the conventional one.

On the other hand, buyers are not willing to buy the sustainable building because they assume the sustainable building is more expensive than the conventional one. Also, they do not have the knowledge to consider the environmental aspect of sustainable buildings such as energy consumption.

3. What is the solution to encourage the stakeholders to have a sustainable building?

Firstly, creating financial and incentive encouragement for the private sector as an added value in realizing the sustainability by the public sector.

Secondly, the selectivity of the technical codes of green buildings instead of obliging them.

Thirdly, using intelligent systems for evaluating the energy consumption of buildings which have done rather than evaluations based on personal judgment

Finally, development, promotion, and economic support by the government are solutions that can be used.

4. What are the specific features of the sustainable office building?

This project is the first real experience of the sustainable building in Mashhad city which uses clean energy at all levels of the architecture of the building. Solar panels, geothermal systems, and recycled water are examples of this to be used to reduce energy costs.

Using a building management system is another feature of the project which has done for each unit and its storages. The building management system is a collection of hardware and software that is installed to monitor and control the different parts of the building. The task of this complex is to continuously monitor the various parts of the building and apply the commands to them. So that the performance of different components of the building is balanced with each other, and in optimum conditions with the aim of reducing unwanted energy consumption and allocating the energy resources only to the spaces which are operating at that moment.

Building management system consists of all build security services, mechanical and electrical services in the project. These services include heating, cooling, air conditioning, elevators, emergency power plants, escalators, lighting control, CCTV, fire alarms, and traffic control.

In the meantime, the use of natural materials (green materials, volatile organic compound colors, recycled plastics, natural gypsum and mineral products) contribute significantly to the reduction of indoor air pollution.

Use of grey waters; water consumed in sinks and rainwater is collected in separate tubes and after recycling and refining it is used to irrigate the green space, wash the area and used for the toilets.

Finally, the use of solar lights in the field to obtain lighting energy at no cost are another features of the project. Meanwhile, free cooling also has applied in the building to reduce the energy consumption.

5. Are there enough standards and rules for implementing green building?

As with other issues, we have no problem in this respect, and there are modern and useful rules for green building, but our main problem is the way in which these laws are

enforced because we lack a coherent governance authority and integrated management for this operation.

5.4.13 Difficulties of sustainable buildings in Iran

The fact is that since the country housing has many trustees, this makes it difficult to enforce many of the building regulations and requirements of this area during the implementation phase.

For example, there are numerous parties, such as the ministry of urban development, the Ministry of Energy, as well as various organizations such as municipalities, and structural engineering organizations each of which is self-assured and related to housing. Meanwhile, the disagreement between these organizations about the relevant standards in the field of building and including the green building makes it difficult to enforce many regulations.

Also, now, even though we all know that green building standards have numerous benefits, but virtually all builders are waiting for them to be dictated only by enforceable and enforceable laws.

Therefore, builders' carelessness comes at the same time as in many advanced societies, including America, Europe, and sometimes Asia, compliance with the requirements of green building standards has virtually become a mandatory law, which requires all of its builders to comply with these standards.

Even in some Asian countries, such as India, incentives have been considered to meet the green building requirements and the government has taken great encouragement to builders, and as a result of this kind of strategy, many builders have been encouraged to comply with environmental and green building requirements. Even though in Iran it is entirely in the opposite side, and not only in the construction process there is not any incentive mechanism to drive manufacturers to this route, but on the other hand, there is no integrated management, unit management, and other necessities which have caused virtually no action to move on this path.

Moreover, when talking about green building standards, various organizations are moving forward, including organizations such as the Standard Organization, the

Municipality, the Ministries of Energy, Roads and Urban Planning. Even though at the stage of implementing the standards for green building laws, neither organizations nor councils accept the others, and they all violate each other.

In fact, when it comes to implementing green building standards, it is imperative that a specific organization must be approved for these standards. However, currently, there is not such an organization at runtime.

Indeed, in the building industry, each organization opposes the others. For example, considering that water use optimization is one of the main elements of the realization of green building, the Ministry of Energy does not cooperate as one of the related organizations in this field, and even though popular methods which have been formed will not be achieved in the implementation.

5.5 The Benchmark- the conventional building

Project Information:

Project Name: Valiahdi office Building

Address: Mashhad, Iran

Consulting company: Huba Design

Date: 2000-2005

Net floor area: 8450 square meter

Cost: 1000 \$ per square meter⁸³

5.5.1 Materials

- brick
- ceramics
- stone
- cement
- concrete



Figure 29. Valiahdi office building

⁸³ (caoi, 2018)

6. Evaluation and results

6.1 Introduction

In this part, the comparison of the sustainable building and traditional building in Iran regarding the cost of the building and energy saving was described.

Also, the economic aspect, as well as the environment issues, have focused within three case studies to help the decision makers such as the owner, investor, tenant and developer to provide the proper way to make the building sustainable. The material which will be used in every project is one of these proper ways.

Three different case studies in different types of non-residential buildings such as high school, library, and office building have mentioned. Also, the analysis of case studies has been supported by the conventional building type.

6.2 Comparison of the sustainable building and conventional building in Iran

6.2.1 The cost of the sustainable building

The essential critique and a barrier to building sustainable buildings is the cost. Researches and their analysis indicates the initial cost of the sustainable building is more than a traditional building. For comparison, need to be reviewed Initial cost and incremental costs in a specific time frame which it is different depending on the level of sustainability and its influence on the environment. Technologies such as photovoltaic and other new equipment are likely to increase costs.

Most sustainable buildings have at least a 2% increase in the initial cost, but this money will turn back because of the high efficiency of these buildings.⁸⁴

Efficient energy consumption will reduce the cost of energy bills, which is a kind of financial savings. Effects of energy consumption reduction will be taken place at leading costs throughout the design process.

The data which has collected from the sustainable building illustrates that the sustainable office building in Iran cost more than conventional building due to the sustainable strategies which have chosen for the sustainable building. Variety of materials, HVAC

⁸⁴ (Danesh Nama, 2013)

system, building management system and other criteria might increase the cost of the building. The table below shows the different cost of sustainable and conventional office buildings.

Type of the building	Benchmark capital cost \$/m2	Capital cost \$/m2	Cost premium \$/m2	Cost premium %	Energy saving \$/m2	Water saving \$/m2	Total saving \$/m2	Simple payback years
Office	1000	1160	160	13.79	11	0.3	11.3	14.16

Table 5. Cost-benefit summary of the sustainable office building⁸⁵

After searching on some real estate agencies websites in Iran, the difference between either renting or purchasing cost of sustainable buildings have become clear. In the market, sustainable office buildings are more expensive to buy or rent. The ordinary people do not know the definition of sustainable buildings; they consider sustainable buildings as a luxury mansion and the people who know this kind of buildings are afraid of the cost of the building. Therefore, just a few people intend to purchase or rent sustainable buildings.

On the other hand, the location of the building in different zones of the city is vital for the owner to decide on sustainable building or conventional building. Because different zones in the city have different prices, maybe the new users of the building intended to have cheaper or more expensive office building according to their budget.

6.2.2 Energy consumption

The results of the sustainable buildings show that between years 2000 to 2008, 15 million kilowatt-hours of electricity consumption in the United States have been saved. Meanwhile, between 2009 and 2012 the energy saving is 63 million kilowatts per hours.⁸⁶

A green building can reduce the water and energy consumption, waste production and carbon dioxide emissions. Therefore, in the sustainable office building, the fossil fuels consumption has decreased whereas the green energy, renewable energy, has increased. Although in the sustainable building in Iran the green energy was used for

⁸⁵ Own table

⁸⁶ (Danesh Nama, 2013)

different aspect such as lights and so on, the fossil fuels were consumed as well. On the other hand, in the conventional building in Iran just the fossil fuels were considered.

6.3 Results

It is difficult to make an exact conclusion for the sustainable building costs especially when they are located in different countries with different standards. In the meantime, it would be difficult to compare different buildings of different countries due to their architectural and cultural features. The cost-benefits of the three different case studies are shown in the table below.

Type of the building	Benchmark capital cost \$/m2	Capital cost \$/m2	Cost premium \$/m2	Cost premium %	Energy saving \$/m2	Water saving \$/m2	Total saving \$/m2	Simple payback years
library	2384	2494	110	4.41	7.5	0	7.5	14.67
High school	2430	2570	140	5.45	7.5	0.6	8.1	17.28
Office	1000	1160	160	13.79	11	0.3	11.3	14.16

Table 6. Summary of the case studies ⁸⁷

The table illustrates different non-residential sustainable buildings. All three case studies in different countries show that the capital price of sustainable buildings is more than conventional buildings. As the table illustrates, the features of a sustainable building add between 4 and 14 % to the cost of conventional building. Furthermore, this amount of money will pay back during the building life cycle. Further, the simple payback for these case studies is between 14 and 17 years.

6.3.1 Cost premium

The cost premium of the building is the difference between the cost of the sustainable building and the cost of the benchmark divided by the price of the sustainable building.

The cost premium of the different case studies was described as below:

The cost premium of the library

$$\frac{110}{2494} * 100 = 4.41 \%$$

⁸⁷ own table

The cost premium of the school

$$\frac{140}{2570} * 100 = 5.45 \%$$

The cost premium of the office

$$\frac{160}{1160} * 100 = 13.79 \%$$

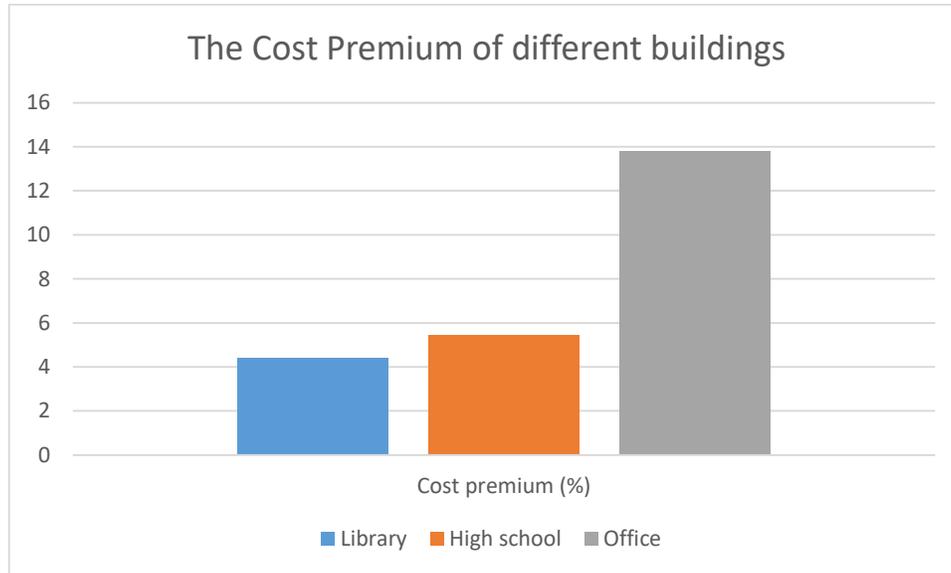


Figure 30. Cost premium of the buildings⁸⁸

6.3.2 Simple Payback

The simple payback is referring to the period which is needed to recover the fund of the investment. Therefore, by dividing the cost of the sustainable building premium by the total annual energy cost, the simple payback was found.

In this research the simple payback was calculated as below:

Simple payback for the library:

$$\frac{110}{7.5} = 14.67 \text{ years}$$

⁸⁸ Own figure

Simple payback for the high school:

$$\frac{140}{8.1} = 17.28 \text{ years}$$

Simple payback for the office building:

$$\frac{160}{11.3} = 14.16 \text{ years}$$

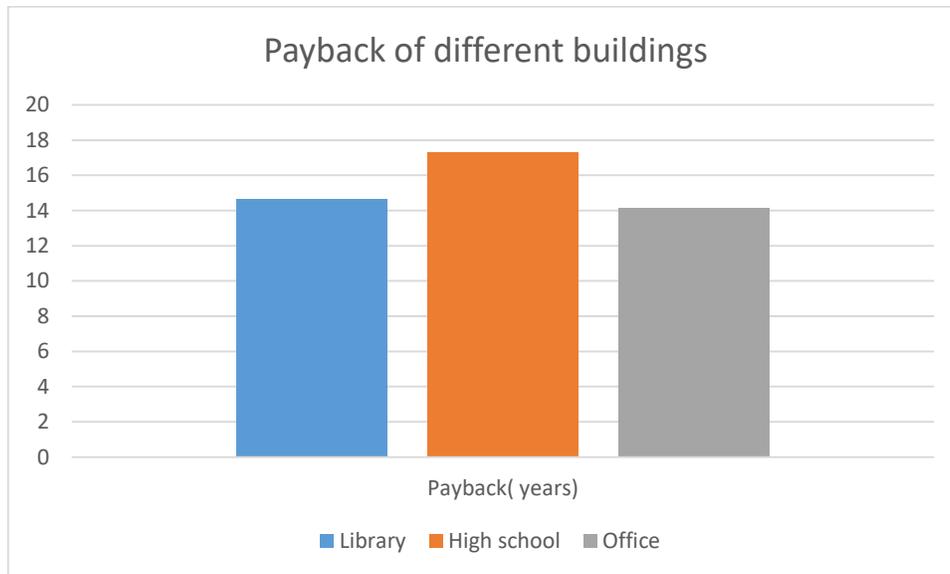


Figure 31. Payback of the buildings⁸⁹

6.3.3 Type of the building and the economic

The strategies of the sustainable building can be matched to all types of buildings such as residential and non-residential.

The usage of the building also must be considered before choosing the sustainable strategies. For example, using natural ventilation has considered in the office building which the case study of it has done, but maybe for the other types of sustainable building such as schools, it is not possible to design natural ventilation. Although different strategies of a sustainable building can be upon on any building, any of them would have the own requirement which must be considered.

⁸⁹ Own figure

6.3.4 Energy and water savings

As three case studies illustrate, all of them have the energy consumption reduction as well as the water consumption reduction compare to the conventional ones. However, the client or the owner might predict to reach the optimistic percentage of energy reducing, but it is difficult to achieve the objectives and reach to the predicted energy saving because of the different factors which were not predicted at the feasibility study and also maybe because of wrong use of the building.

6.3.5 The motivation of the users

(Manatū Mō Te Taiao, 2005) Indicated that the users of the two existing case studies are satisfied with the buildings and already confirmed by evaluations. The two existing case studies have real user satisfaction, and also the productivity is the potential benefit of these buildings. Also, a survey by probe study methodology has done within the almost 50% of the buildings. The subject is because of the project`s nature which the client and the user have motivated, the relative ease of design attempt of the sustainable strategies, and the interest.⁹⁰

6.3.6 limitation of the sustainability

Being doubt if different sustainable strategies will be adapted to the building or not, and doubt to the cost of implementation for sustainable buildings are the limitation for making the building sustainable.

Besides, in the case study which has done in this master thesis, lack of knowledge about the sustainable buildings in Iran could be another limitation because there are not too many buildings to use as a benchmark for comparing the cost.

6.3.7 Comparison between the standards of the case studies

Firstly, in New Zealand, the New Zealand Green Building Council uses Green Star assessment tools for non-residential sustainable buildings. The tools evaluate the environmental impact that is a direct consequence of a buildings site selection, design, construction, and maintenance.

⁹⁰ (Leaman, Bordass, 2001)

The frame has eight different environmental impact categories. Meanwhile, an innovation category is another impact. These categories are set out as below:

- Management
- Indoor Environment Quality
- Energy
- Transport
- Water
- Materials
- Land Use & Ecology
- Emissions
- Innovation

All of the categories included credits that address initiatives that improve or have the potential to improve a buildings environmental performance. Points are awarded in each credit for actions that demonstrate the building has met the credits criteria.

A weighting factor is then applied to each category to reflect the overall importance of the environmental issue addressed by the category. These weightings vary between each Green Star tool to reflect the different environmental impacts of each building type.

Secondly, although the sustainable building in Iran is not familiar yet, efforts have been made in this regard such as the establishment of the Green Building Council of Iran. IGBC is a non-governmental council with the aim of developing and promoting design, construction and use of environment-friendly buildings established in Tehran in 2008 for encouraging the implementation of Green Building Construction Practices. Meanwhile, the target of the Iran Green Building Council is the development of sustainable and Eco-friendly buildings.

Consequently, in this master thesis, the structure of assessment tools in New Zealand is considered even for the case study in Iran due to the not proper structural assessment tools in the country. In the meantime, the aim of following the same structure for the case studies is to make it more comparable and understandable.

7. Conclusion

In this master thesis, comparing the green building with the conventional building as well as the importance and necessity of running the sustainable buildings was expressed.

Generally, a sustainable building saves the energy consumption, water and electricity, reduce greenhouse emissions, improvement of air quality and health, the welfare of the residents, protection of national resources and a significant reduction in costs. The aim of creating a green building is to improve the quality of the climate and also to prevent the adverse effects of construction on the environment.

Meanwhile, saving and optimizing the energy consumption and applying the sustainable energies, currently, have no role in the culture of Iranian construction. Iran compared to other countries in the world, does not have the proper standard in the building industry and also entering a new method in the building industry and its adoption is difficult for engineers, but in developed countries as the new technology enters to the construction industry the culture of using this technology also teach to the people.

Also, it is important to note that the country does not have any problem with the standard of building materials and technology shortages, but the problem is the correct use of the standards, methods, and technologies. Buildings in Iran are still in a traditional way, and still, this method is accepted by the people, so there is no modern industry for buildings in Iran.

In the meantime, non-specialized implementation and non-standard materials which used in buildings are another reason for reducing the life and quality of buildings. Further, the average life cycle of the buildings in Iran is around 30 years, but the average life cycle of buildings in some countries is about 100 years. Consequently, by using the smallest and easiest possible equipment, the most significant amount of renewable energy can be achieved to reduce the energy consumption as well as having a better environment.

Therefore, although a sustainable building in Iran costs more than a traditional building, this price will be given back in a few years due to the high efficiency of the building and also the increased cost is different due to the sustainable strategies.

Hence, sustainable buildings will optimize the energy consumption and reduce the energy cost which is the advantage of sustainable buildings to save money.

Besides, in sustainable buildings, by reducing the fossil fuels, the consumption of green energy will be increased which is an economic benefit itself.

The cost premium for these three case studies is between 4.4 and 13.8 %. Besides, these three case studies are not enough to compare the different features of the sustainable buildings, but it can be discovered that the sustainable buildings are more productive than the conventional buildings and they might have satisfied the users.

Also, it is clear that the strategies of sustainable buildings could be adapted to all type of buildings regardless of the location of the countries.

Therefore, the strategies of sustainable buildings are increasing. It means these strategies are not only for energy saving and water consumption but also for a full range such as all ecological issues, waste management, and materials.

In the case studies, either the design or the strategies which have chosen for the buildings were proper, and they fulfill the satisfaction of the users.

In Iran, if a sustainable building has award-winning, it means it has high architectural standards which it makes the building cost higher.

However, the sustainable building will be successful when an expert design team leads the project from the early design. One famous and well known sustainable building attracts the people to think about building a sustainable building instead of a conventional one. Finally, a sustainable building is better than conventional building because they present user satisfaction which encourages the others to make their building sustainable.

7.1 Suggestion and recommendation for sustainable buildings in Iran

The easiest and most feasible way to implement the green building in Iran is to increase the awareness and demand of the people, as well as creating incentives among the builders. Also, of course, the economic sentiment of some builders in the sphere of construction industry makes them somewhat reluctant to enter this area, while the necessary cultures in this regard can encourage them to move in this direction.

For example, green building builders, although their output can be a bit more expensive than the others, on the other hand, they should know that this type of construction is a benefit for them and their final product is separated qualitatively from the other buildings.

At the same time, it should be considered that by creating a culture among people, they involve with the sustainable buildings spontaneously. Although they may have to pay more for the purchase of green buildings, on the other hand, the people will receive back the extra cost during the lifecycle of the building due to the lower energy consumption and water saving.

Meanwhile, people need to reach a level of maturity and awareness that they require the builders to observe the elements of green buildings. Consequently, this demand will have a two-way effect and will also require builders to use the standards in order to satisfy buyers.

Moreover, considering the existing conditions and the disparity between the relevant organizations and the economic view of the builders in Iran, there is a hope that green standards would be more implemented in the future.

However, it is too much remains to be achieved in the country. Therefore, it is not possible to realize the sustainable buildings in Iran in a short time.

However, there are some suggestions for optimizing and reducing cost in the sustainable buildings as below:

- Design the building for maximum sunlight usage during the day in winters. In summer, the temperature may be a little bit high depends on the location of the site in the country so if using daylight is considered in the project, the proper strategy for avoiding warmth of daylight must be in mind.
- Use of coal waste in concrete, fly ash, which is an excellent and cheap alternative for cement depending on the type of project. It can be 30 to 50 percent in the concrete mix. Reducing the consumption of concrete and increasing the durability

and strength of the concrete will bring the reduction of environmental impacts of cement which is the advantages of this method.⁹¹

- Using sustainable materials contribute significantly to the reduction of air pollution in the interior.
- Use of a green roof. Using a green roof in the sustainable building works as a filter to prevents noise get inside the building. Also, it helps to absorb the carbon dioxide.
- Granting loans and other facilities to encourage the building industries to implement the sustainable buildings
- Development of the instruction and the culture of green buildings within the country
- The policy of the government for providing facilities and tax reductions with the long-term economic benefits
- Place the windows in proper place to use the maximum daylight
- Windows must be able to be opened even in winter to use natural ventilation instead of an air conditioner
- Use of wind turbines if it is feasible. In the design of high rise buildings due to the high altitude and the possibility of wind turbine placement at the top of the building, it is possible to use maximum wind power to produce electricity.
- Using sustainable materials: environmental building materials increase the value of construction projects and reduce harmful effects on the environment. These types of materials usually have one or several advantages such as the efficiency of the use of energy resources, water, and natural resources protection, the promotion of the health and well-being of the residents and the other people. Building materials also have significant effects on the inhabitants of the buildings.
- Use of Photovoltaic solar panels to make the hot water. The photovoltaic solar panels also prevent the direct sunlight from heating the ceiling up in summer.
- Use of external walls, use of two shells, to store the heat in winter, control of radiation in the summer.
- Use of fluorescent lights to reduce the energy consumption

⁹¹ (Danesh Nama, 2013)

- Use of renewable components
- Lowest damage to the canvas and natural habitats
- Use of a natural ventilation system which helps the fresh air ventilate the building
- Installing some fixtures to optimize water consumption. For example, by using low flow plumbing fixtures, the water consumption will decrease
- Use of VOC-free paint for reducing the number of harmful particles of air
- Reducing the energy consumption by using sensors to turn off the lights when there is no need of lights

Declaration of Authorship

I hereby declare that the attached Master’s thesis was completed independently and without the prohibited assistance of third parties, and that no sources or assistance were used other than those listed. All passages whose content or wording originates from another publication have been marked as such. Neither this thesis nor any variant of it has previously been submitted to an examining authority or published.

Location, Date

Signature of the student

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