ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL

HOW GREEN CONSTRUCTION ENHANCES THE QUALITY AND PROFITABILITY OF OFFICE BUILDINGS FOCUSING ON LEED: A CASE STUDY OF ENERGY-COST ANALYSIS AND BENEFIT ASSESSMENT

M.Sc. THESIS

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Department of Civil Engineering

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JULY 2024

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ISTANBUL TEKNİK ÜNİVERSİTESİ ★ LİSANSÜSTÜ EĞİTİM ENSTİTÜSÜ

OFİS BİNALARININ KALİTESİNİ VE KARLILIĞINI ARTIRAN YEŞİL YAPI: LEED ODAKLI ENERJİ MALİYETİ ANALİZİ VE FAYDA DEĞERLENDİRMESİ ÜZERİNE BİR ÇALIŞMA

YÜKSEK LİSANS TEZİ

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Sana ADIBNIA, a M.Sc. student of İTU Graduate School student ID 501211123, successfully defended the thesis entitled “HOW GREEN CONSTRUCTION ENHANCES THE QUALITY AND PROFITABILITY OF OFFICE BUILDINGS FOCUSING ON LEED: A CASE STUDY OF ENERGY-COST ANALYSIS AND BENEFIT ASSESSMENT”, which she prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

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Date of Submission : 24 May 2024
Date of Defense : 5 July 2024

To the brave souls in Iran who stand
with courage and resilience for freedom,

FOREWORD

I am deeply grateful to my supervisor, Dr. Emre Gürcanlı, whose guidance, expertise, and unwavering support were instrumental in shaping this thesis. Their insightful feedback and encouragement have been invaluable throughout this journey.

I would also like to extend my heartfelt thanks to the jury members Dr. Deniz Artan and Dr. Özge Akboğa Kale for their time, thoughtful critique, and constructive suggestions, which have significantly enriched the quality of this work. Their expertise and dedication to academic rigor have been pivotal in refining my research and ensuring its scholarly merit. I am sincerely thankful for their contributions to this endeavor.

July 2024

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ABBREVIATIONS

AHP : Analytic Hierarchy Process
BCR :Benefit Cost Ratio
CBECS : Commercial Buildings Energy Consumption
DFD : Design for Dessembly
GA : Genetic Algorithm
GB : Green Buildings
GGBS : Ground Granulated Blast-furnace Slag)
GSM : Ground Square Meters
HVAC : Heating, ventilation, and air conditioning
LCA : Life Cycle Assessment
LEED : Leadership in Energy and Environmental Design
NPV : Net Present Value
PP : Payback Period
REC : Reducing Embodied Carbon
SDGs : Sustainable Development Goals
USGBC : The U.S. Green Building Council

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HOW GREEN CONSTRUCTION ENHANCES THE QUALITY AND PROFITABILITY OF OFFICE BUILDINGS FOCUSING ON LEED: A CASE STUDY OF ENERGY-COST ANALYSIS AND BENEFIT ASSESSMENT

SUMMARY

Studies found that there is a huge difference between the conventional office building and the eco-friendly one concerning energy use and electricity consumption. The in-depth investigation on this regards was carried out with the help of advanced modelling software, Design Builder. It is concluded that the principles of a sustainable design play a very important role in saving resources and reducing operational costs throughout the life cycle of a building. Green buildings embody sustainability and demonstrate the potential of these design principles in significantly reducing the impact of the environment in built environments. Important issues, such as climate change and resource depletion, have been catered for by these green buildings through the reduction of energy use and dwindling dependence on limited resources. This further takes a boost from the incorporation of renewable energy resources and new technologies, which no doubt position green buildings as the future of architectural designs.

This intrinsic relationship between built environments and human well-being emphasizes the need to envelop environmentally sustainable design into building practices. As a result of their effects on indoor air quality, admission of considerably more natural lighting, and excellent thermal comfort, green buildings enhance the physical health, mental well-being, and productivity of the users. Research has shown that better indoor air quality is related to a lower prevalence of respiratory difficulties and allergies, while the exposure to daylight has been linked with a better mood and higher productivity. Thermal comfort maintains attention and decreases stress. In this way, green buildings are not a benefit for the environment but also for considerable improvement in living quality for all those who work inside them.

On the financial side, green office buildings bring benefits during a building's lifetime. Some of the more direct benefits include reduced operational expenses through lesser energy and water consumption. Another large component of benefits is an increased value of assets through the higher market premiums for green buildings that are therefore adept at enhancing efficiency and sustainability. Added to this is the fact that there are a number of legislative incentives aimed at greater sustainability, including tax rebates, grants, and preferential speeding-up of permitting procedures. These incentives facilitate an even more attractive initial investment in green building, making it more economically viable.

It's nothing short of a game changer: the shift toward green office buildings. It's thoroughly sustainable development in the environmental, economic, and social dimensions. Sustainable development ameliorates the pressure on the environment, increases economic resilience, and enhances the social fabric of our communities. In its approach, it assures that the benefits of green buildings do not stop at the buildings'

respective physical borders but contribute to a more comprehensive concept of sustainable development.

Realizing the full potential of green buildings will ultimately require a continuation of the spirit of collaboration across the spectrum—from architects to engineers, from policymakers to the occupants of these buildings—all with the same goal of supporting innovation through a steadfast commitment to sustainability. This collective effort, therefore, becomes very important in surmounting other challenges that may continue to confront green building practices on the road to universal embracement. In addition, constant research and development are needed for the upgrading of technologies and techniques to be more efficient, cost-effective, and accessible.

Conclusion: It is not only a trend or niche within architecture. Green building points to an important change as regards a more sustainable future, and its more fair design. This building design and construction approach takes most problems related to the environment, economic benefits, and social well-being into consideration. Continuing collaboration, increased innovation, and strong commitment are some of the ways toward development of built environment that combines with nature and benefits human well-being. This vision of green buildings is what will guide us on to sustainable development and bring human activities into harmony with the rest of nature.

OFİS BİNALARININ KALİTESİNİ VE KARLILIĞINI ARTIRAN YEŞİL YAPI: LEED ODAKLI ENERJİ MALİYETİ ANALİZİ VE FAYDA DEĞERLENDİRMESİ ÜZERİNE BİR ÇALIŞMA

ÖZET

Yeşil binaların iç mekan kalitesi ve iş performansı üzerindeki etkilerini anlamak, günümüzde çevre dostu yapıların öneminin arttığı bir dönemde, akademik ve endüstriyel anlamda önemli bir araştırma alanı olmuştur. Bu binaların, enerji, su ve malzeme kullanımını azaltarak çevresel etkiyi minimize etme hedefi, çeşitli ölçeklerde tanınmasına ve takdir edilmesine yol açmıştır. Ancak, yeşil binaların iç mekan kalitesi ve iş performansı üzerindeki gerçek etkileri hala net bir şekilde anlaşılamamıştır.

Bu bağlamda, yeşil binaların iç mekan kalitesi ve iş performansı arasındaki ilişkiyi derinlemesine incelemek üzere bir araştırma yapılmaktadır. Tehran'da inşa edilen bir yeşil bina ile geleneksel bir bina arasında Design Builder ile karşılaştırmalı bir analiz yaparak, karbon ayak izi, enerji tüketimi, termal konfor ve işgücü memnuniyeti gibi faktörler üzerinde odaklanılmalıdır. Beklentilerin aksine, yapılan araştırmalar yeşil binaların genellikle daha iyi termal konfor sağladığını, ancak işgücü memnuniyeti açısından bazı geleneksel binaların öne çıktığını göstermektedir. Bu bulgular, yeşil binaların performansı hakkındaki algıları gözden geçirmek ve daha iyi anlamak için yeni soruların ortaya çıkmasına neden olmuştur.

Yeşil binaların tasarımı, sadece çevresel faktörleri değil, aynı zamanda sosyal ve ekonomik faktörleri de dikkate almaktadır. Bu binaların inşa edilmesi ve işletilmesi, sürdürülebilir malzemelerin kullanımı ve enerji verimliliğinin sağlanması gibi çeşitli zorluklarla karşılaşabilir. Bununla birlikte, yeşil binaların çevresel etkisinin azaltılmasına ve iç mekan kalitesinin iyileştirilmesine yönelik potansiyeli, bu zorlukların üstesinden gelmeyi gerektiren önemli bir motivasyon kaynağıdır.

Yeşil binaların oluşturulması ve uygulanması, yüksek başlangıç maliyetleri ve belirsiz yatırım getirisi gibi finansal zorlukları içerebilir. Ayrıca, yeşil binaların sertifikasyonu ve performans değerlendirmesi karmaşıktır ve çeşitli zorluklarla karşılaşabilir. Bununla birlikte, bu tür zorluklar, yeşil binaların çevresel ve sosyal faydaları göz önüne alındığında, genellikle aşılmaya değerdir.

Sonuç olarak, yeşil binaların iç mekan kalitesi ve performansı üzerindeki etkileri karmaşık bir konudur ve daha fazla araştırmayı gerektirmektedir. Ancak, bu tür binaların çevresel ve sosyal faydaları, onların teşvik edilmesi ve desteklenmesi gerektiğini açıkça göstermektedir. Bu nedenle, yeşil binaların tasarımı, inşası ve işletilmesi üzerine yapılan araştırmaların devam etmesi ve bu alandaki bilgi birikiminin artması önemlidir. Bu, hem çevresel sürdürülebilirlik hem de insan refahı açısından olumlu bir adım olacaktır.

1. INTRODUCTION

Worldwide, there are notable green buildings that attempt to diminish the use of energy, water, and material resources, while at the same time enhancing environmental care and human well-being. From this perspective, the current study explores the relationship between green buildings, IEQ, and job performance in office environments. This is done by conducting a detailed comparative analysis between two office buildings; one which is built based on long-established standards for green construction; the other built using conventional design approaches. Our study was quite comprehensive and delved into a look at a number of critical factors, such as CO2 concentration levels, thermal comfort, occupant happiness, and absenteeism rates. This research thus contributes to the formation of a more prudent view on the performance and satisfaction gap in such contexts. On the one hand, the green buildings offer performance conduits with slightly improved thermal comfort, yet on the other hand, conventional buildings express higher levels of overall occupant satisfaction. Such an important result challenges well-established assumptions related to the effectiveness of green buildings and calls for providing a more prudent view about the performance-satisfaction gap that characterizes these contexts. In addition, green building encompasses more than just recycling and reusing substances and resources.

It also includes the social and ecological context of the sites on which they are constructed; the recognition of the interaction within the built environment and with the surrounding environments. The trend in the rise of green building practices and the potential benefits that they impart in fostering environmental, economic, and social gains have headlined intensive studies in this area in the current decade. The con side is associated with significant challenges emerging during the creation and adoption of green buildings.

Such obstacles include high initial costs and uncertainty about returning on investment in green projects of the construction sector. The stakeholders are normally missing the proper knowledge and skills inherent in the construction sector, thus creating a gap in the effectiveness of the performance of sustainable practices. Yet, the process involved in obtaining green building certification and assessment gets so complicated that it may seem impractical to score a green building for most developers and builders. It is also possible that inherent tensions and trade-offs exist between the different requirements and features that are part of green building design. For instance, some of the benefits that emerge from adherence to very stringent energy efficiency standards may impact factors such as access to natural light or ventilation, and the aforesaid are factors that can impact human satisfaction and comfort.

Given this paramount complexity and the issues involved, the final objective of the dissertation is to offer added knowledge to practitioners, policymakers, and researchers in the domain of green buildings. In this context, having considered a wide dataset supported by big data analytics and life-cycle assessment methodologies, this research applies a practical case—an office building in Turkey—to refer the produce of analysis related to the cost-benefit perspective structured to assist behavioral changes and added further actions in the domain of green building practice.

In the end, this research is an attempt to reduce the gap in knowledge in the area and gives value to empirical data and real-world examples in contributing to the advancement of green building.
We hope that a more explicit comprehension of how these structures should be optimized for human comfort and satisfaction will be realized by describing the details of green building performance and occupant satisfaction. In addition, the research can be sensitized through the designing of policies and strategies that can contribute to the realization of embracing green building practices in a wide scope, making the built environment healthier and more sustainable. These shall therefore represent efforts that are in support of a transformation shift in the industry of construction in answering the needs of an evolving global emphasis on sustainability and resilience.

1.1 LEED

For green buildings, the LEED certification certainly works as an accepted rating system. It was developed by the United States Green Building Council for the promotion of ecologically friendly methods of building and to have a system for measuring the sustainability of a structure.

With heightened awareness of the negative impact traditional ways of building can have on the environment, interest in sustainable building approaches has grown recently. Building owners and developers have used LEED certification to express commitment to sustainability and environmental stewardship increasingly.

LEED-certified buildings are made of sustainable materials, energy efficient in design and operation, and have a minimal impact on the environment. Buildings to be certified must pass a variety of rigorous criteria, among them those dealing with materials and resources, indoor environmental quality, water and energy efficiency, and innovation in sustainable site development.

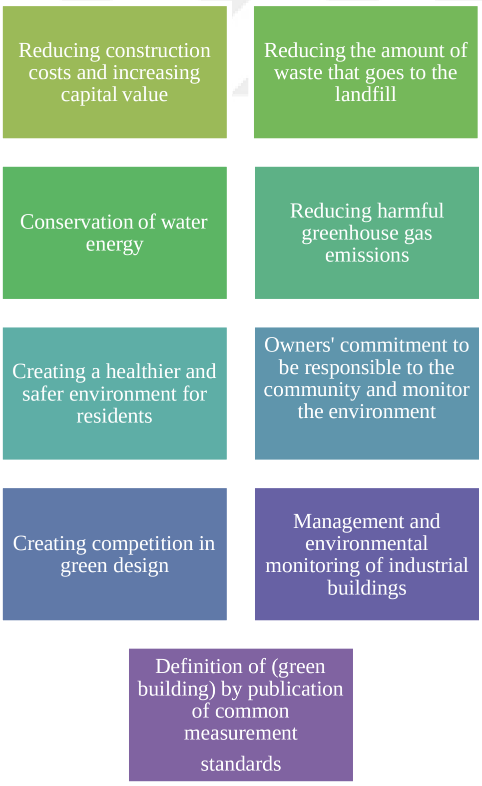

Figure 1.1: LEED Goals

1.1.1. Background information on the cost of building an office building, and the additional costs associated with pursuing LEED certification

Many influential factors, such as location, size, materials, design, and construction methods, may increase the cost for an office building. The U.S. Census Bureau estimates that the average cost of a new office building in 2021 was about $330 per square foot. However, a multi-story, complex building in an excellent location may be more than $1,000 per square foot while a very simple construction of low-rise can be closer to $100[1].

The Leadership in Energy and Environmental Designs is basically a green building certification scheme which would foster and enable the sustainable building practice with several extra costs, all above the cost of construction. These extra costs can be :

LEED registration fees: Depending on the size and complexity of a project, these could be around $5,000, paid to the U.S. Green Building Council.

Consultant fees: Hiring a LEED consultant ensures the project meets all of the requirements and accelerates processes of certification. These charges may range from a few thousand dollars to tens of thousands of dollars, based on the size of a project and the level of certification under pursuit.

Paperwork costs: This includes the LEED certification, which requires a lot of documentation in terms of sustainable material usage, construction waste monitoring, and water and energy usage. Works can add up easily.

Added building costs: A LEED-certified building would require application of most of the expensive materials, all the way from low-emitting sealants and paints down to specialty equipment installations like HVAC and lighting systems that use less energy. These things add up to 5–10% of building cost.

Operational costs: Although a building's green features and better energy efficiency may reduce running costs in the long term, achieving a LEED certification involves some upfront fees with respect to staff training and maintenance of sustainability.

The added cost of obtaining LEED certification, depending on the degree of certification pursued and the peculiar requirements of a project, will generally increase total development costs for an office building by 2-10%. However, in the long run, it may justify the investment through reduced consumption of energy and water, better indoor air quality, and increased satisfaction of tenants.

The conventional planning, design, construction, and operation phases view buildings as stand-alone systems and ignore the fact that they are an integral part of more complex, larger systems. Therefore, solving one problem may cause other problems to manifest in the system.

The integrated approach promotes good teamwork on the other hand. This process is harnessed from the holistic approach of the project team towards the building and all its systems, emphasizing links and enhancing communication between experts and stakeholders throughout the project. It rejects linear planning and design techniques that may result in unsatisfactory outcomes and crosses boundaries between disciplines. Though the term "integrated design" is most generally associated with new construction and building renovations, an integrated approach can have use at any point in a structure's life cycle.

Though the integrated design approach requires more time and work up front, freedom to influence the design in terms of fitting LEED goals is maximized during this initial stage of design. One of the essential elements necessary for the successful completion of a LEED project is integrated design.

Although this may appear as routine project management, new skills have to be acquired by practitioners, which they may not have required in other professional capacities. They include an in-depth understanding of natural processes, critical thinking and questioning, cooperation, teamwork, and active communication. The integrated process facilitates a unified team of professionals who earlier were independent entities and, therefore, represent an alternate way of thinking and working.

It is more labor-intensive and collaborative than traditional approaches from the early stages of conceptualization to the design phase. It consumes more time for the formation of the team, setting of objectives, and analysis before arriving at or implementing any decisions. This, however, shortens the total duration of the project and might even save resources.

1.1.2 Procedure for LEED certification

The project is meant to complete the prerequisites and credits that the team has opted for. For a project preliminary and final reviews are done after submission of papers for certification. The final evaluation report comes with the project's final score and certification level as well as technical guidance on credits requiring further work to be achieved. A team can appeal if they feel there was need for more thought.

Figure 1.2: Credit Categories

1.1.3 LEED rating system

The five areas that make up the LEED rating system are Building Design and Construction (BD+C), Interior Design and Construction (ID+C), Operations and Maintenance (O+M), Neighborhood Development (ND) and Homes. Energy efficiency, water conservation, indoor environmental quality, materials and resources, as well as innovation represent different aspects of sustainability according to separate credits in each area. Depending on the number of points it receives, a project can secure any of four levels of LEED certification: Certified, Silver, Gold or Platinum.

Figure 1.3: Adaptations

Figure 1.4: LEED Points

1.1.4 LEED v4.1

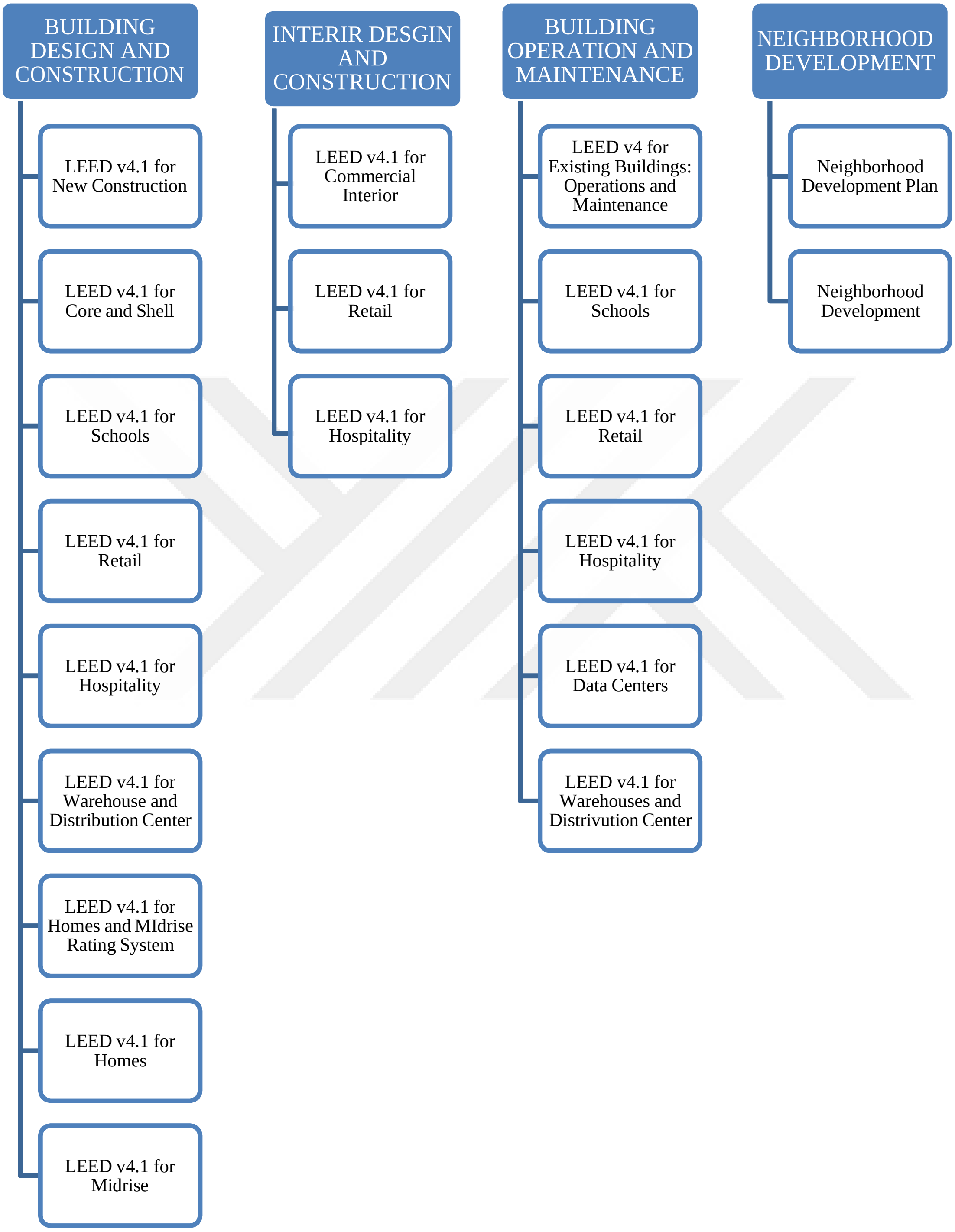

Figure 1.5: LEED v4.1 Protocols

1.2 The Economic Benefits of Green Construction

The average operational cost reductions within the first 12 months surpass 10%, and the cost savings throughout the five years exceed 16%, as the table in the lower right-hand side illustrates. For investments in new green buildings and green renovations/retrofits, owners and investors can see an increase of 9% in their buildings' asset value. The evidence is clear that these buildings do provide value to the owners of assets and also deliver the operational cost savings that have been so much expected [2] .

According to Word Green Journal published in 2021, engineers who complete more than 60% of their projects environmentally benefit from their expanded understanding and expertise in green construction, which allows them to accomplish superior outcomes.

• Compared to the global average of 59%, those with a high level of green participation track operational expenses more frequently (71%) [3].

•It is thus especially noteworthy that they record first-year operational cost reductions of more than 16% for new green buildings and retrofits and more than 20% for green renovations and retrofits.

According to these results, companies that engage in more green building may be able to get the desired outcomes, which may in turn spur further investment and create a positive feedback loop .

Table 1.1: Cut back in Expenses

	New Construction	Renovation-Retrofit
Cut back in expenses in the next 12 month	10.5%	11.5%
Cut back in expenses in the next 5 years	16.9%	17%
Capital Gains	9.2%	9.1%

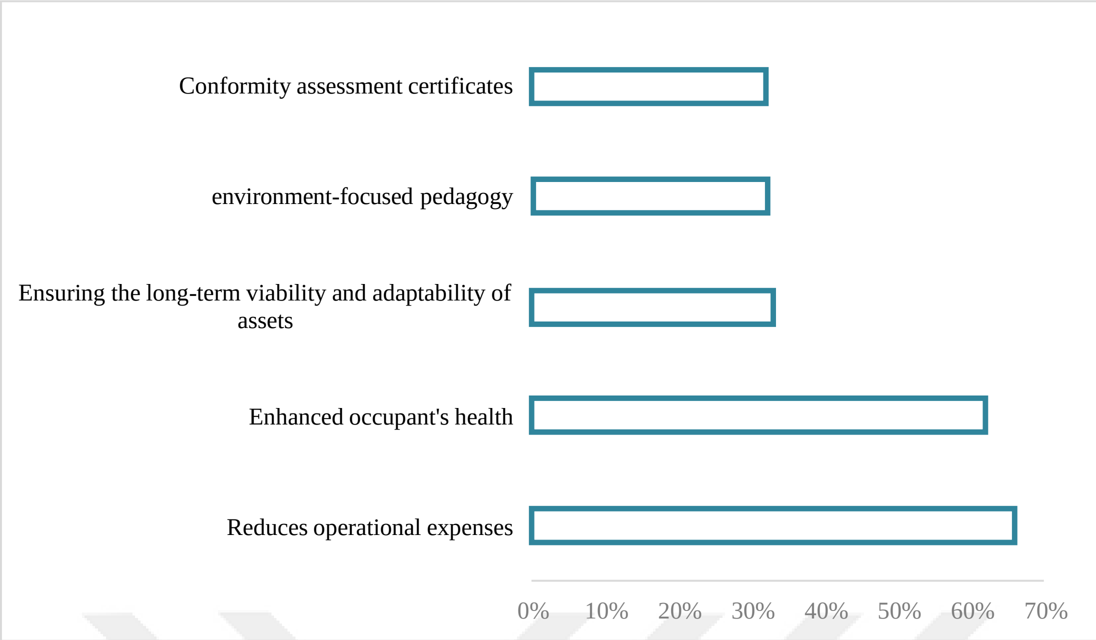

Figure 1.6: Dodge Data and Analytics

1.3 Countries And Regions Top The List For LEED Green Building

The U.S. Green Building Council released its annual Top 10 Countries and Regions for LEED outside of the United States in February. [4]

Mainland with more than 68 million gross square meters, China topped the list. The list honors marketplaces that are utilizing LEED to design healthier interior environments for people, consume less water and energy, lower carbon emissions, and save costs for households and companies. Over 210 million gross square meters of space and approximately 7,800 recognized structures are located in the top countries and regions.

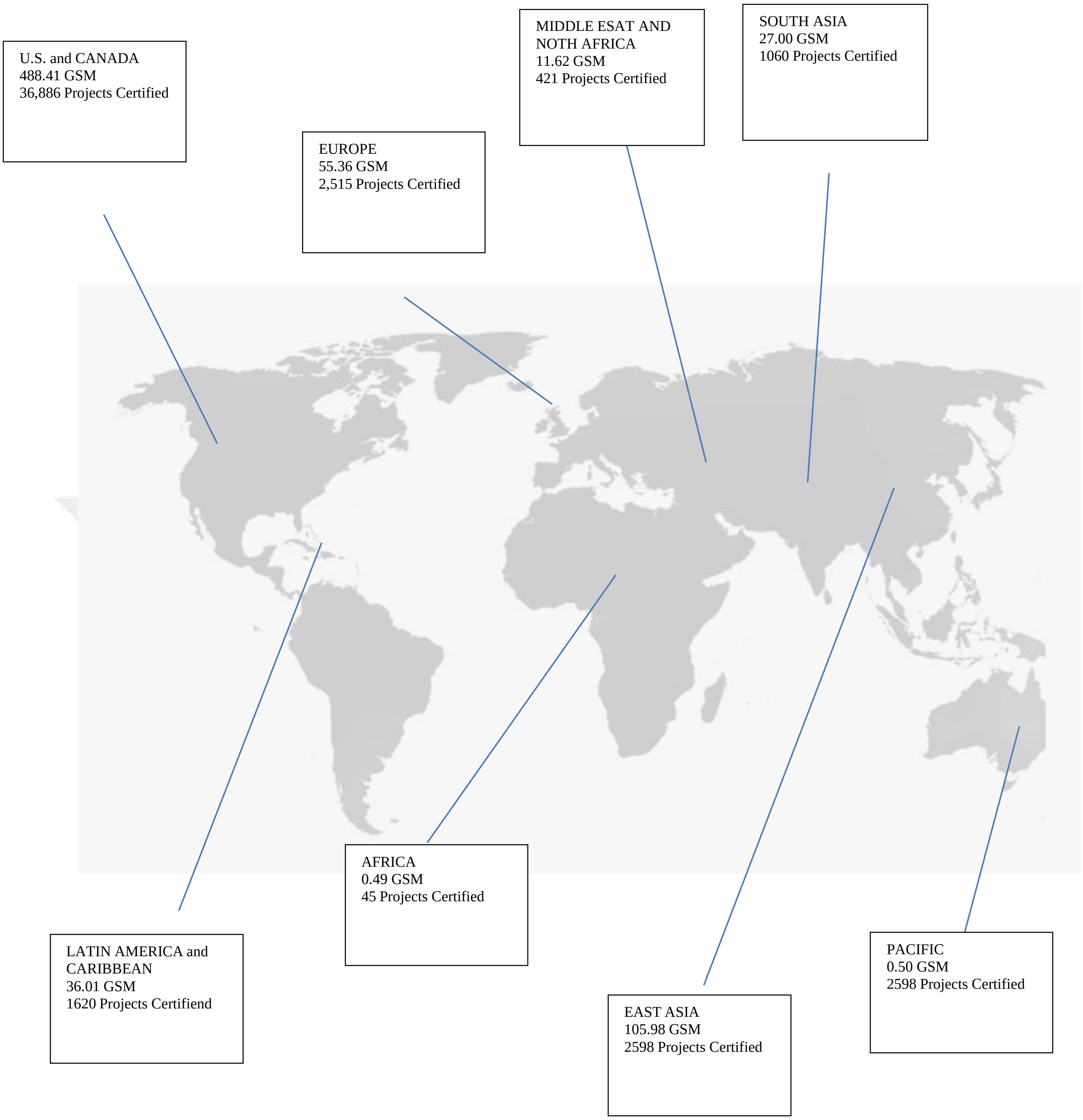

Figure 1.7: The yearly Top 10 Countries and Regions for LEED

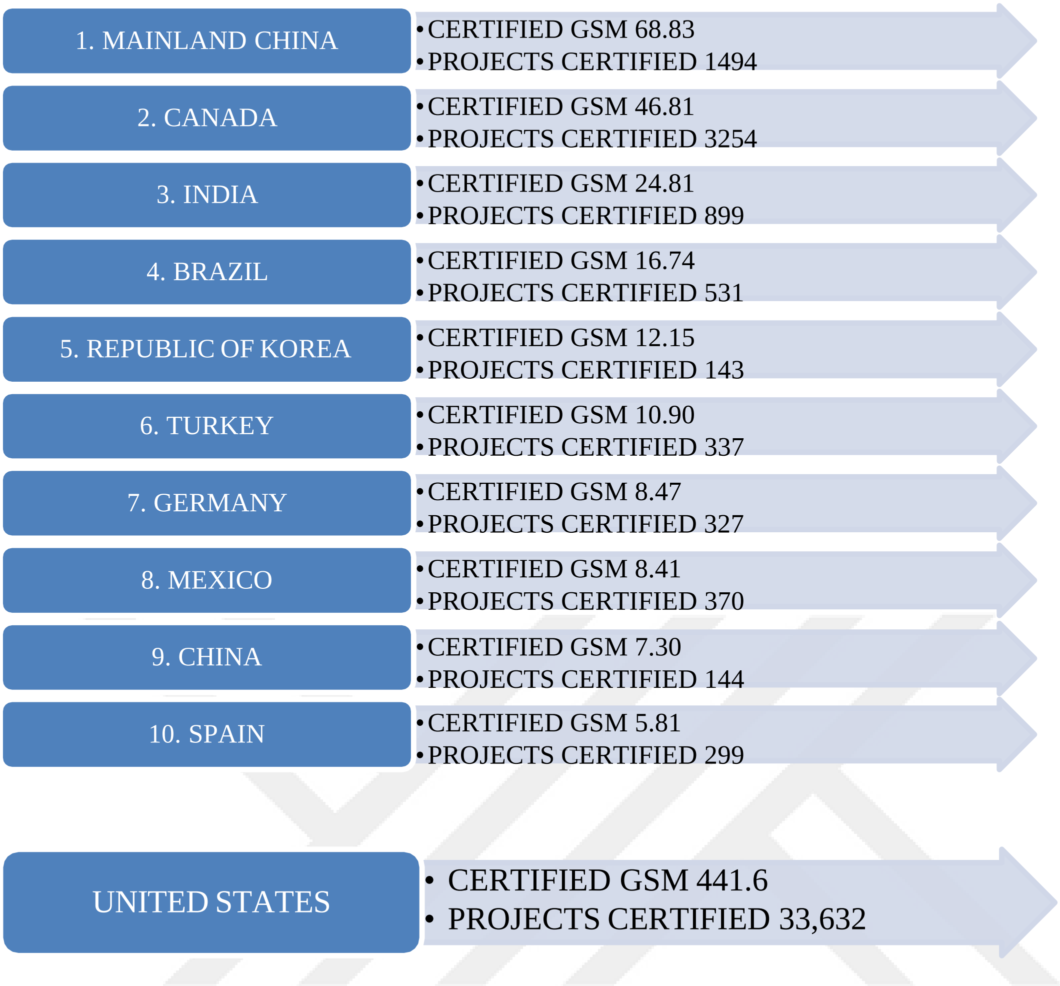

Figure 1.8: Ranking Countries

The influence which buildings, towns, and communities have on people is, however, still held in high regard by the USGBC and other industries. The USGBC launched the Living Standard campaign to grow its green building activities around the world and ensure that LEED remains the most used leadership standard and leading living standard. The campaign looks to convene big and small stories that will shine a light on how sustainability efforts like USGBC, LEED, and others are working to improve quality of life in communities around the globe. That is why this campaign is going to provide the ideas for using storytelling to build a more sustainable society.

1.4 Office Buildings VS. Residental Buildings

Workers occupy office buildings as their places of employment. Office energy efficiency is equally vital. The fact that changes in the structure of the primary energy sources cannot be anticipated in the near to medium term makes investments in energy efficiency very necessary to achieve the goal of lowering greenhouse gas emissions by the year 2030. Because buildings have a high carbon intensity and a quick development rate, they provide the greatest opportunity for reducing emissions and conserving energy. Despite this, there are still missing pieces of information concerning the incorporation of decarbonization of the built environment into the overall system of the economy.

1.4.1 Energy consumption patterns

Commercial buildings, which include offices, have an intensive energy consumption per square foot compared to residential buildings because of extensive lighting, HVAC systems, and office equipment [5].

1.4.2 Economic Effect

Energy costs are also significant for residential and commercial users. The impact, however, in the economy is likely more far-reaching where offices are concerned as offices are an entity representing larger operating and therefore larger utility bills [6].

1.4.3 Environmental Effect

Large quantities of CO2 are emitted by commercial buildings. Enhancing the energy efficiency of office buildings can ensure a considerable reduction in GHG emissions and thus help in overall environmental sustainability [7].

1.4.4 Occupancy

While residential buildings are occupied for the whole day, office buildings remain inhabited only during business hours. Some strategies for maximizing energy efficiency in offices include smart building technologies that create variable lighting and space temperature control linked to occupancy patterns [8].

1.4.5 Regulatory drivers

State and local building codes tend to stress energy efficiency in residential and commercial construction. However, there could be initiatives or standards addressing sustainability in commercial buildings, such as LEED certification for offices [9] .

1.4.6 Technological Advancements

The technologies for smart building systems, energy-efficient lighting, and sustainable materials are amply applicable in residential buildings. Moreover, the scale of implementation in large office buildings may matter [10].

1.4.7 Health and productivity in offices

Energy-efficient office designs are likely to underline characteristics that work for the occupant's benefit, which can include natural lighting and air quality, further affecting health and productivity. This trait would not be as emphasized in residential buildings [11].

While both residential and office buildings benefit from energy efficiency, the scale of impact and considerations differ. Energy-efficient measures in offices can give a very significant contribution to reducing overall energy use and environmental impact. However, advances in residential energy efficiency are important for a comprehensive, sustainable approach to building design and operation.

1.5 Social Justifications for Constructing Environmentally-Friendly Office Buildings

Green constructions have great impacts not only on the environment and economy but also on the social health and community. Some of the social reasons for improving the green buildings industry are:

Table 1.2: Improving Industry Reasons

Promotes the growth of the national economy
Fosters a feeling of camaraderie and belonging
Promotes the use of environmentally friendly and socially responsible strategies in business operations.
Has an appealing aesthetic.
Enhances Employee Efficiency
Enhances the Health and Well-Being of Occupants

1.6 Energy Consumption

Recent statistics by the US Department of Energy Energy Information Administration, EIA-DOE ,stated that the commercial sector consumes 2.0 billion tce of primary energy or 11.4 percent of all energy that the global world consumes. According to the International Energy Agency, IEA, this energy that is consumed has registered a significant increase in the last two years. It now stands at around 17.5 billion tce. Office buildings are perhaps the most public part of the commercial sector and they use almost one-fifth of the energy of this sector. At the beginning of the 21st century, office buildings embodied 17% of all gross floor space and 18% of all energy consumed by commercial buildings in the US. The stock of office buildings in the UK has been estimated at 130 million m2 in 2004 and has continued to rise [13].

Only 17% of the last five years total amount of consumed energy was business; slightly less than 4% more.

The commercial sector is one of the major sectors constituting structures and equipment that uses massive energy, particularly in the consumption of office buildings. As part of its initiative to have some understanding of building characteristics associated with energy use, the U.S. Energy Information Administration conducted a regular Commercial Buildings Energy use Survey, CBECS in the past. In fact, this countrywide sample survey indicates the count of commercial buildings in the US. CBECS presents information on the amount of energy consumed in commercial buildings according to numerous varied primary functions carried out in the buildings, forms of energy source, and uses to which the energy is put. The most recent CBECS was fielded in 2018. There were more than 5.9 million commercial buildings in the US in 2018, totaling some 96.4 billion square feet. These buildings used some 6.8 quadrillion British thermal energy units, quads. Primary fuels used in commercial buildings contributed to about 72% of end-use energy in the commercial sector. Warehousing buildings and storage buildings bore dominance among commercial structure related to primary building activities, followed by office building these buildings also derived major share of floor space square footage. However, all other types of commercial buildings, consumed smaller amounts of energy compared to office buildings.

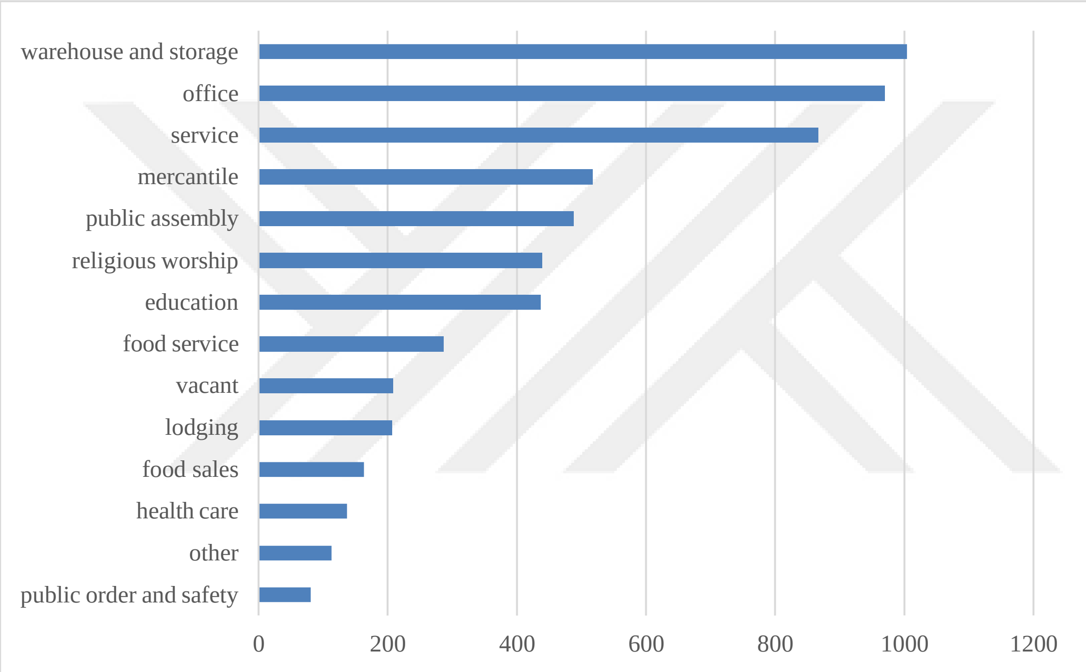

Figure 1.9: Number of U.S commercial buildings by principal building activity 2018 (thousand)

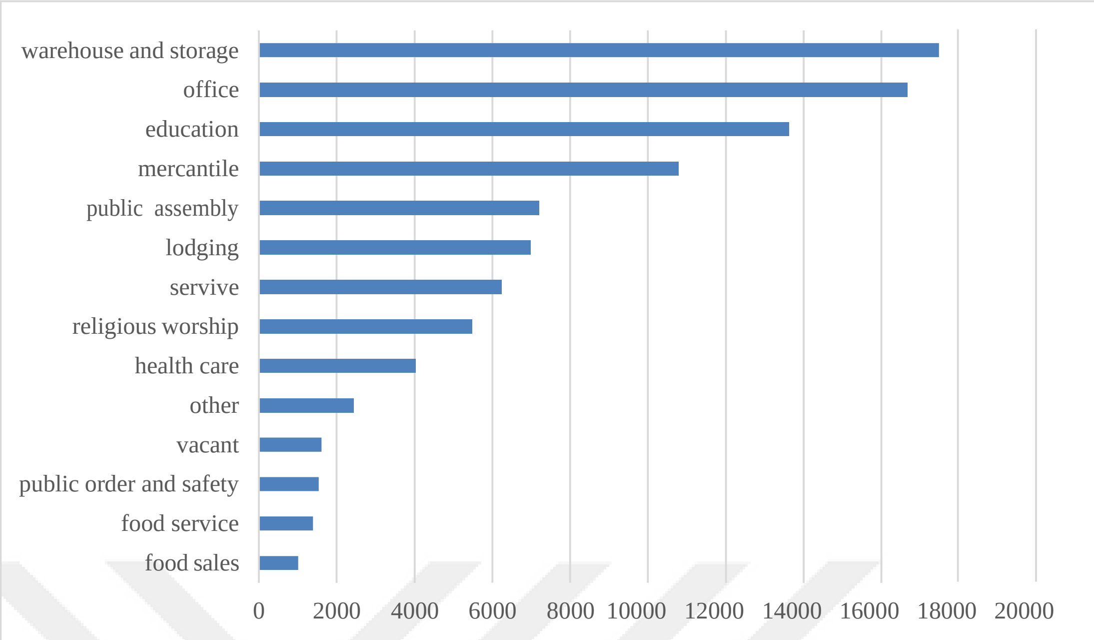

Figure 1.10: Total floorspace of U.S commercial buildings by principal building activity, 2018 (million square feet)

Space heating accounts for the largest primary energy use of commercial buildings in the United States.

Even though all business buildings have different energy needs, space heating accounted for over 32 percent of commercial building energy use in the United States as far back as 2018. As far as energy uses in commercial buildings are concerned, ventilation and lighting took second and third places, respectively, and they consumed almost 10 percent of all energy used in commercial buildings in 2018. The annual and regional differences in proportional percentages of space heating and cooling depend on the climate and weather [14].

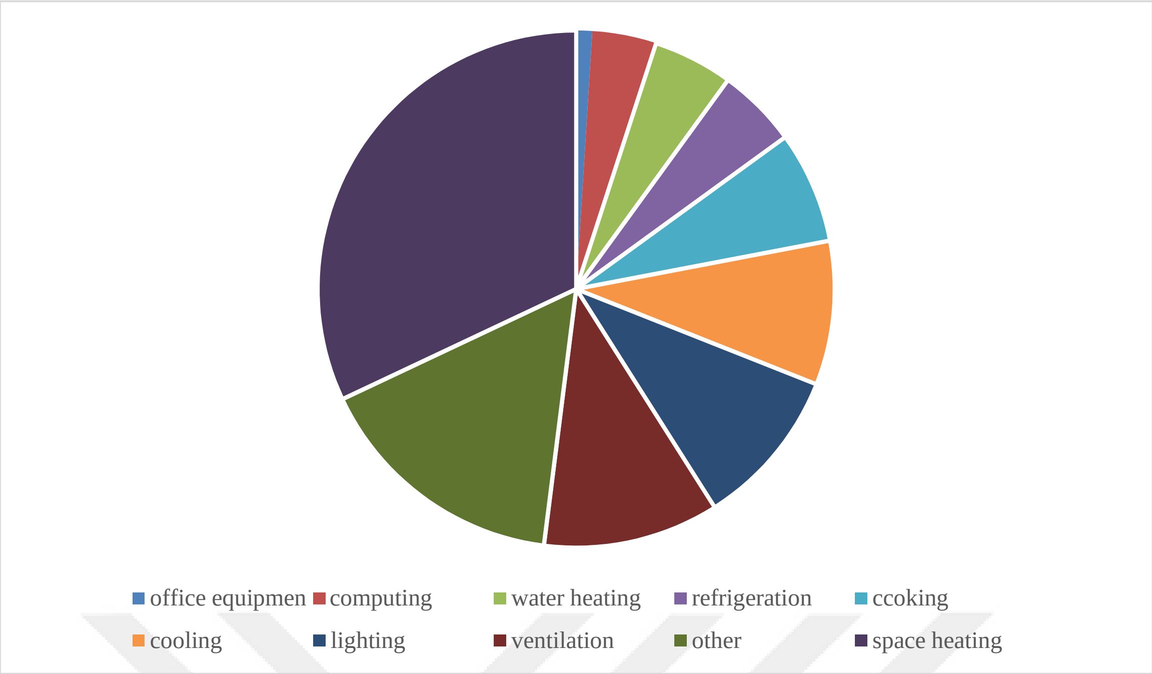

Figure 1.11: Major fuels consumption by end use in U.S commercial buildings, 2018

In 2018, the main energy sources used in U.S. commercial buildings were electricity and natural gas.

In 2018, natural gas made up 34% and electricity 60% of the total energy used in commercial buildings in the United States. Electricity is used by buildings for all purposes. In commercial buildings, natural gas is typically used directly to heat water, and interior spaces, and run appliances or cooking and cooling [15].

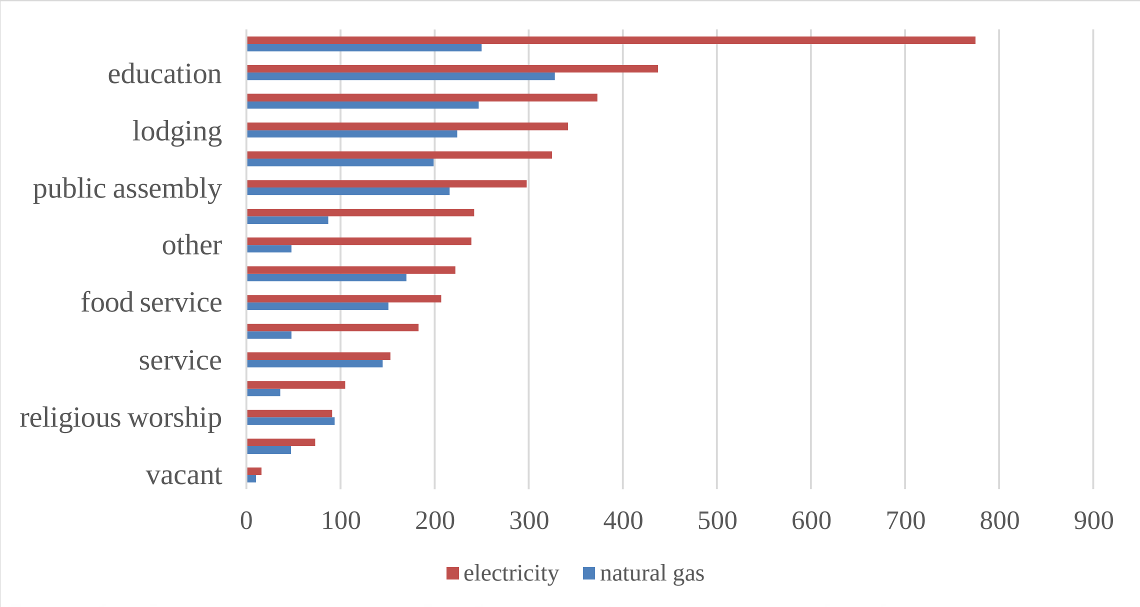

Figure 1.2 Electricity and natural gas consumption in U.S. commercial buildings by principal building activity, 2018[16]

1.7 BMS

The Smart Building Management System in İran is a system that utilizes the latest technologies to provide ideal conditions and facilities for residents, while simultaneously optimizing energy consumption in the building. The primary goal is to achieve efficient use of existing resources and energy, resulting in both improved comfort for residents and cost savings in the initial investment.

The system controls various aspects of the building, including smart temperature control, automatic security management, intelligent fire extinguishing, and more. Control and access to the smart management system can be done through dedicated software within the building and even remotely via the Internet.

The logical reason for using a smart management system in buildings lies in the cost reduction and increased efficiency it brings. Large buildings often negotiate with different companies for services such as fire detection, fire extinguishing, energy-saving in electricity consumption, fuel consumption savings, CCTV cameras, and HVAC management. The multitude of contractors results in additional costs, such as multiple wiring for different systems and the need for personnel with various expertise to operate these systems. A smart management system addresses these drawbacks, reduces costs, and enhances overall efficiency to lower maintenance expenses. In the context of the technical operation of the " Building Management System ":

Table 1.3: Technical Operations of BMS

Building Management System	Percentage
Local Control: The system operates with local controllers that manage individual spaces. These controllers, produced by a consortium, handle the management of each independent space. The second level is a central software managing all local controllers and security cameras.	39%
Communication: All information is transmitted over the local building network, minimizing the need for extensive wiring. This reduces potential points of failure and speeds up fault detection.	24%
Fault Tolerance: The two-tier management system ensures that even if communication between the local controller and the central software is interrupted for any reason, the local controller continues its operations. This ensures continuity in managing and controlling the essential aspects of the space.	37%

As for the capabilities of the "Smart Building Management System Iran," it includes:

1.7.1 Building security management

Each unit is equipped with a local controller that manages entry and exit using a digital identity recognition system (magnetic card or digital code). In case of an incorrect password, the system alerts the central software and raises an alarm, providing detailed information on the location of the issue.

1.7.2 Remote monitoring

The central software, which is displayed on the building map, has the exact location where problems may be. If there happens to be a problem, one can contact the police and the control room displays and stores video footage of the problem location.

It offers one-stop shop solutions, ensuring security to the building occupant while providing cost savings and efficiency.

1.7.3 Crisis management

The application has a red button in every local controller used under special events like heart attacks, assault, or even general feelings of danger. This button triggers the alarm, passing information to the central software. If need be, police or fire department contacts are made and the footage of the incident is displayed and retained at the control room. This central software, combined with the building map, pinpoints the exact location of the emergency and projects it onto the main monitor.

1.7.4 Fire management

Timely detection of fires and their origin plays an important role in building fire management. Smoke and heat detection sensors are fitted in all units, and the same is connected to the local controller of that unit. In case of detection of any smoke indicating a fire or heat indicating outbreak of fire, the local controller triggers an alarm indicating the occurrence of fire to the central software. It also notifies the fire department and the unit owner, displays and stores relevant images of the fire scene, and indicates on the building map in the main monitor the exact location of the incident. If the unit is equipped with firefighting equipment and an automatic control system, then it can act autonomously or by instructions from the control room to automatically suppress the fire.

1.7.5 CCTV camera management

In units where surveillance is needed, one or more networked CCTV cameras are installed, providing rotation and zoom capabilities. Unit owners can determine in their local controller whether they want their cameras controlled from the control room. In the control room, the system manager can view any authorized camera at any time and, if necessary, save the corresponding footage. In case of any significant event in the building, the footage is automatically saved.

1.7.6 Building energy management

Different uses of energy use in buildings usually provide lighting, heating, and cooling. Controlling excessive use from peak hours and avoiding wasting energy use during vacant hours can help save some energy. Majorly, most electrical energy is consumed by lighting and fan coils. If the unit is unoccupied, the fan coil shall be switched off and all lights switched off. At exactly this particular hour of the morning, the fan coil system is activated to preset the unit to the normal temperature. In unit-occupied hours, the temperature in the unit is within the preset range and controllable automatically by the fan coil. The local controller controls fan coils at each unit, while temperature programs for energy efficiency are received from the central software.

1.7.7 Worldwide green office buildings

During its first decade, the Bullitt Center has produced nearly 30% more energy from its rooftop solar panels than it has consumed. This surplus could power 41 Seattle homes for a year. Since its Earth Day 2013 inauguration, the Bullitt Center has unequivocally demonstrated that net-positive energy buildings can be achieved anywhere.

Figure 1.13: Bullitt Center in Seattle [17]

Angel Square stands out with its distinctive double-skin glazed façade and features several floors with winter gardens, offering breakout spaces and significantly improving the working environment. The building also boasts a large, full-height atrium that ensures excellent natural light throughout. It gets its power from pure vegetable oil and obtains this oil from grape seeds grown on the cooperative's own agricultural land. Additionally, with LED lighting and an advanced system for recycling waste and rainwater, One Angel Square is among the most beautiful examples of green buildings.

Figure 1.14: One Angel Square is lighting the way to a greener future in Manchester. [18]

Shanghai Tower is 2,073 feet high, consisting of 128 stories; it is a mega-tall skyscraper that has been Shell Platinum and LEED Core certified. The system is specifically detailed to provide the maximum light transmission factor and features a bonus insulating effect, resulting in an energy-saving feature that warms cooler outside air during winter and dissipates interior heat in summer. Besides, the green space occupies one-third of the area of the tower. Because of this, the tower is capable of operating perfectly on a trigeneration system with the help of the heat engine, which simultaneously produces electricity, cooling, and heating.

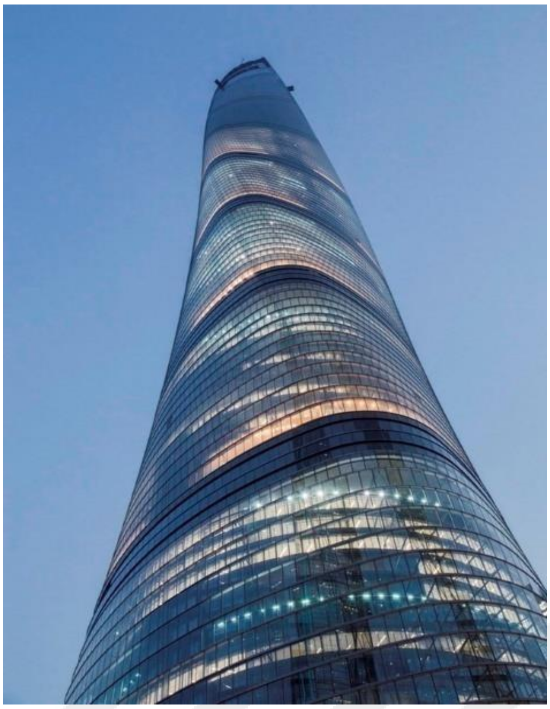

Figure 1.15: Shanghai Tower [19]

It has a dramatic 15-story atrium that serves not only as an office space but also, in some sense, as an exterior window to the social hub, thereby minimizing the building's impact on the environment. The client, a progressive developer from the Netherlands, is keen on pushing the frontiers of architectural innovation. The vision is to make this building a leader in every way: sustainability, technology, innovative workplace design, and elite structural and exterior engineering. This should inspire the business environment. But it will also be one of the flagships of smart offices.

Its façade spans around 13,000 square meters of glass in different shapes and sizes, arranged alongside solid aluminum panels. The north-facing atrium façade has 70% glass, allowing only indirect sunlight to enter but without overheating. The office spaces are located in U-shaped blocks facing east, south, and west to optimize available space. The east and west elevations have 45% of the area as glass and 55% as concrete for heating equilibration. The south elevation is 40% glass, which has concrete areas covered by photovoltaic panels to add efficiency in the building's energy performance.

Figure 1.16: The Edge, Deloitte Netherland's Amsterdam [20]

Table 1.4: Top Green Buildings Energy Consumption

	Energy Consumption Reduction
Bullitt Center	86%
One Angel Square	80%
Shanghai Tower	80%
The Edge	produces 102% of its own energy

1.8 What Lighting Resources and Equipment Can Be Controlled?

In a smart building, all light sources including ceiling, wall, desk, decorative colored lights, fluorescent and are controllable individually or in groups. With this method, all LED lamps can be controlled without the need for any hassle. The “Dim” lights are informed of their status and can be turned on and off or the security system of the smart building can be managed. Among the main advantages are high accuracy, remote control capability, (Biometric System) capability, and detection of smoke and waterlogging (Zone) on mobile phones, sending SMS to cover the area. In doors, windows, curtains, shutters, and shades, curtains and shutters (installed inside or outside) and shades can be easily controlled with a touch on the control panel. When leaving the building, you will be informed of the open and closed status of all doors and windows by looking at the display screen. Door control is centralized using fingerprint sensors and magnetic cards, which, in addition to creating more security, allows for classification and scheduling of access to the building. In a smart building, the temperature of the rooms can be adjusted according to the need and by dividing them.

Also, it will significantly reduce energy consumption in case of its functioning is put under the condition of the presence of residents in the building. Audio and video system: In a smart building, the use of music and film archives is possible according to personal taste and individually from each room and… which is available in all Sound Box, DVB, TV, Radio, CD, DVD: Music and film archives are used as desired. DVDs and CDs of the building's rooms without transferring the device or even the video iPhone. By ringing the iPhone, the image of the reference will only appear on the desired screen or all reflected pages. Also, when residents are not present in the building, the image of the reference and the time of the visit are recorded and you will be informed after returning from it. Automatic watering system: The irrigation of flowers and plants, fountains, artificial waterfalls can all be controlled from the control panel. Smart building applies the same in controlling flower and plant irrigation in the yard or inside the building.

1.8.1 Control of pool, sauna, and jacuzzi facilities

In a smart building, turning on and setting the temperature of the sauna, finding out the time the sauna reaches the desired temperature, and automatically filtering the pool or jacuzzi are all easily possible. Communication systems (telephone, answering machine, central telephone, and internet) are among the features of a smart building that support multiple phone lines, answering machines, central telephones, and telephony In-House Video services. Additionally, in a covered environment, video phones can be used.

1.8.2 Electrical equipment in a building

The smart building keeps one updated on the condition of all electrical equipment and gives control over them. For example, after the washing machine is done, it warns that the job is complete. During the usage of a vacuum cleaner, at the sound of a telephone, it automatically turns off. This way, the smart building nearly rules out the possibility of not hearing a telephone when working with noisy house appliances or because of too high volume of music being played. It will also give a consumer the necessary warning in case he leaves something in the refrigerator.

1.8.3 How to access and control facilities in a smart building

It allows one central control panel to control all devices intelligently in the building, making it easy to know their status of operation. This is because the display screen equipped with touch technology does not require any other device for input, thereby adding to its use.

Control via radio waves This technology makes it possible to control wirelessly, using a very simple wireless device, a smart building with the help of very simple radio waves. The major advantages are remote Control or distances, which does not require a direct line of sight, a Tablet PC, PDA controller. It is possible because of remote control availability. The status of the building can be remotely accessed and controlled with the smart building. This feature you can use either by telephone, SMS, or through the internet.

Scenario A: Scenario refers to running a set of tasks by merely pressing one button or touching the control panel. The usage is focused on convenience and speed when it comes to creating an appropriate space.

Automation Smart buildings have taken control of part of daily and repetitive work to create comfort for you. Using temperature, light, wind, rain, humidity sensors, and person detection sensors enables the automatic function of the system to include predetermined tasks for more comfort or optimized conditions to provide necessary warnings.

1.9 Smart Buildings Benefits

1.9.1 Convenience

Smart buildings take care of some repetitive tasks and make life easier for residents. With a single gesture, scenarios can be set up to precisely adjust the environment. A user-friendly and multilingual software interface makes life in smart buildings easier.

1.9.2 Safety

In critical situations such as fire, waterlogging, and theft, smart buildings announce warnings that can significantly prevent damage or further damage. Special features such as zone alarms, accurate person detection sensors, fingerprint sensors, and digital camera control and recording enhance safety for homes.

1.9.3 Flexibility

Flexibility in implementing and using smart technology features is a key advantage. With the tools provided by this technology, adding these features to existing homes usually does not require rewiring or replacing existing equipment in the building. The use of smart keys and displays inside the building or with remote control for programming and executing commands, as well as the ability to control all building facilities using mobile phones, help all residents access building facilities.

1.9.4 Energy efficiency

Managing energy consumption in smart buildings has a significant impact on energy savings. Linking lighting and ventilation systems to the presence of people and optimizing room temperatures at different times of the day are examples of energy management. Also, automatic control of curtains and shutters to prevent direct sunlight from entering the building in summer saves electricity for cooling devices.

1.10 Future Look

A Building Management System (BMS) in a smart building is hardware and software installed for monitoring and control functions involving main elements and systems of the building. The objective of this collection involves constant monitoring of various parts of the structure and commanding in such a way that performance between the various building components is harmonized and optimal conditions are achieved, thus reducing unwanted consumption and focusing energy resources only on areas during their operation[13].

This system integrates and coordinates public lighting panels, diesel generators, fire alarm and extinguishing systems, security systems, elevators, traffic control systems, central motor components like chillers, boilers, and circulation pumps, and several other control systems using one or more computers.

The smart building management system has three parts: sensing, controllers, and actuators. These sensors are to take measurements of the environmental parameters and to transmit this information to the system. This information may be, for example, temperature of the external and/or internal environment, temperature of the heating or cooling fluid, level of light in the environment, level of humidity, quantity of gas in air, presence or absence of the people in the area, etc., and all this is absolutely important for optimum operation of the vital system[21].

The controllers are parts of the system that fetch information from sensors or receive commands from operators by using in-built software, and they forward the control signal accordingly to the operating units.

Actuators can also be viewed as the parts of the system which receive the commands sent from the controllers, and respond accordingly. The following are some examples for the operators: electrical fluid valves, adjustable air ducts, circuit breakers, and relays, which turn on and off electrical current. However, these three parts are inter-related with each other with the help of a communication mechanism. The two major significant parts include: Communication media, such as wires, fibre optics, radio waves; Communication protocols or languages, such as BACnet and LonWorks.

The communication media based on the spoken language or communication protocol enables the sensors, controllers and actuators understand each other. However, open protocol systems are popular in breaking this monopoly and giving the smart building project managers free action. The hardware and software products by these manufacturers are sold based on open protocols, typically in use in smart buildings. It is upon the buyers to buy the offered hardware and software products of those companies. As such, it follows that smart building project consultants and managers need to be very careful in their selection of manufacturers so that they do not end up being forced to comply with the monopoly of one company in the long run[22]. Systems with open protocols allow manufacturers enough freedom of action to build a unique and separable device and take comprehensive and pervasive solutions to all smart building needs. Another characteristic of the open protocols is the ability to communicate any part of the system with other components without the need for hardware and software intermediaries.

1.11 Cost-Effective Strategies for Reducing Embodied Carbon

An engineer’s role in reducing carbon cannot be overstated. By adopting effective architectural strategies, you can dramatically reduce the environmental impact of your projects. Before we dive into these strategies, let's first review why they are important in today's world. Every action in the construction process exhibits an environmental footprint. From the extraction of raw materials, transportation, and assembly of building components, there’s always a consequential carbon footprint. REC is pertinent in the early stages of a project, contributing hugely to global greenhouse gas emissions. Therefore, its reduction is crucial in our quest to decarbonize the built environment[16].

1.11.1 Consideration of materials

Everything begins with the material selection. As an architect, it’s essential to understand that every material has its embodied carbon footprint. Prioritize using low embodied carbon materials like bamboo, timber, or recycled steel. Where possible, reduce material usage by exploring new architectural designs and methods that require fewer resources[17].

1.11.2 Modular construction

The modular system is designed off-site and then sent for local assembly. Significantly reduces construction waste, transport emissions and energy consumption compared to conventional construction methods. Furthermore, they speed up construction and save money.

1.11.3 Design for disassembly (DfD)

DfD is a design strategy where scenarios of future renovation or demolition of a building are taken into consideration. In this process, the building's life cycle can be elongated, reusability of building components can be increased, and the carbon footprint can be reduced.

1.11.4 Use of renewable energy sources

Diversifying a building's energy mix by incorporating renewable energy sources such as solar, wind or geothermal energy not only reduces operational carbon, but can also indirectly reduce carbon in the energy sector and turn it into another strategy to transform the good.

As a result, strategies for reducing fixed carbon are many and varied. This is where we need architects to take the initiative and adopt these strategies to change the way we think about architectural design. After all, we architects create buildings. And let's shape a better low-carbon future[23].

1.11.5 Towards a resource-efficient and sustainable future through life cycle assessment and circular economy

Adapting our architectural practices to incorporate the principles of Life Cycle Assessment (LCA) and the circular economy is not merely a trend, but a necessity. Sustainability isn't just a fashionable buzzword; it's intrinsic to the future of architecture and the livelihood of our planet. As architects, the decisions we make now will shape our world for decades to come. Therefore, it's our duty to make informed decisions that reduce embodied carbon and support circularity.

While this guide contains a lot of information, it is by no means exhaustive. Each building project is different and presents its own set of problems. Still, having insight into the working of LCA, circular economy, and taking up the path to reducing embodied carbon, we can take the first step in designing and constructing beautiful buildings that are also environment-friendly.

"Reducing Embodied Carbon is central to a project's sustainability impact—not just for today, but for the future. This shift needs new ways to plan, design, build, and maintain our structures. As architects, we are in the unique position of being able to set this change in motion.". By being informed about the consequences of our actions and through more sustainable materials and methods, we contribute to the collective societal effort toward a goal of "reduced carbon emissions" [24].

"The insight that Life Cycle Assessment—an analytical method for evaluating and decreasing the environmental impact of structures throughout their whole life cycle—can bring into play in helping to lighten the carbon footprint of our works is immense. This approach offers, therefore, the practical view of what the total environmental impact of our building is beyond the energy it uses or the waste it produces [25].".

"Most of the practices in architectural practice that integrate the principles of a Circular Economy increase our efforts to minimize embodied carbon. Moving away from the linear model of "take-make-dispose" to a circular one enables dramatic improvements in resource efficiency, with concomitant reductions in environmental impact. Adopting the concept of a circular economy into architecture means designing deconstruction, recyclability, and minimization of waste from buildings, but endless reuse of resources.

1.12 Green Construction Challenges in Iran

The construction industry in Iran has traditionally employed conventional methods, which are widely accepted due to cultural norms surrounding building practices. When new technologies or methods enter the construction industry, they often encounter resistance from engineering communities, which can be attributed to a lack of precise understanding of the benefits of these innovations. It is important to note that our country does not face challenges in terms of standardisation of building materials or a shortage of technology. Rather, the main obstacle is a cultural barrier to adopting these advancements. A case in point is the intermittent and short-term consideration given to industrialisation in construction practices, which lacks comprehensive, strategic oversight. The average lifespan of buildings in Iran is approximately 30 years, in stark contrast to other countries where buildings can endure for up to 100 years. While national building regulations, encompassing 22 topics, have somewhat altered traditional attitudes towards construction, industrialisation has yet to firmly establish itself [27].

The green buildings concept is no exception to this context either. Many initiatives have been made to encourage the development and uptake of environmentally friendly construction practices in Iran, for instance, the establishment of the Green Building Council in Tehran back in 2008. This is a nongovernmental organization that provides specialized solutions pertaining to the sustainability of the construction industry through regulations and professional training initiatives, including energy labelling programs that indicate both energy efficiency and thermal comfort conditions within buildings. However, this research aims to achieve the closest design to that of a sustainable office building, utilizing sustainable materials available in the market.

1.13 Concrete Design Sustainability

The significant impact of the built environment on climate change is well-documented, with concrete production emerging as one of the largest contributors to emissions within the sector. The manufacturing of cement and the production of concrete together account for approximately 8% of global greenhouse gas emissions, a figure that surpasses the entire aviation industry's contribution [28].

Over the past two decades, emissions from cement and concrete production have doubled. Currently, the industry consumes around 30 billion tonnes of concrete annually, a threefold increase compared to forty years ago. Notably, concrete is now the second-most consumed substance worldwide, second only to water.

Businesses and construction firms must truly work toward the net zero targets and the United Nations' SDGs by starting to utilize a few of the most promising alternatives in sustainability to traditional concrete. Businesses must embrace innovative materials and ways of construction to reduce the environmental impact caused by the built environment.

Addressing the substantial emissions from concrete production requires a comprehensive strategy that includes the adoption of sustainable materials and practices. By doing so, the construction industry can contribute significantly to global efforts to combat climate change and promote sustainability.

1.13.1 Sustainable alternatives to traditional concrete

Green concrete significantly improves over conventional concrete through several important innovations, including:

-Waste Material Usage: Green concrete uses wastes such as cement substitutes, which not only reuse by-products of industries but also save natural resources.

-Less Energy Consumption: Manufacturing green concrete requires reduced energy, which eventually decreases the emission of carbon dioxide and, ergo, minimized environmental damage.

-Durability: Green concrete is more durable and requires less maintenance, which increases its lifespan.

Green concrete was invented in Denmark back in 1998. It is made from wastes that are obtained from various industries like power plants, mining, and quarrying processes, and incinerator residue. They enhance the concreteness workability and finishability, rise in quality, lower permeability thus reducing the chances of cracking. Green concrete is also more cost-effective, as it would take fewer new raw materials into its production and require less transportation because it uses reclaimed materials.

2. LITERATURE REVIEW

In the study entitled "IMPACTS OF CONSTRUCTION RISKS ON COSTS IN LEED-CERTIFIED PROJECTS," [29], the construction risks are identified with a focus on cost impact issues related to the Consultant, Contractor, and Subcontractor in LEED-certified projects.

"Sustainability Considerations of Green Buildings: A Detailed Overview on Current Advancements and Future Considerations" [30] gives additional expenses of sustainable buildings, such as LEED certification costs and design costs.

The work "An Investigation of the Selection of LEED Version 4 Credits for Sustainable Building Projects" [31] focuses on how a project team selects its appropriate goals and tells even more about their decision-making processes. One of the examples of green building certification is the Leadership in Energy and Environmental Design— the program by the US Green Building Council, prevalent in most modern societies for achieving sustainable building before and in the view of climate change and resource depletion. The program has more than 146,400 projects worldwide. At the same time, though compliance with the requirements of LEED brings multiple advantages for the design performance of a project, creating valuable positives for the community, it at the same time includes increased costs and added burdens. In this research, decisions made by stakeholders in 222 LEED New Construction version 4 certified projects from September 2014 to March 2020 are looked at relative to making proper choices of LEED goals by project LEED project teams. The paper provides insights on how to choose goals for a LEED project and associated LEED credits at the target certification level, how to link and trade credit options. Based on these results, certain positive recommendations are made on ways that may allow LEED project teams to reach target certification levels and that might encourage the authorities to further better local green regulation.

The paper "An analysis of the LEED green building certification system on construction costs" [32] of Uğur and Leblebici represents an analysis carried out for estimating the cost-benefit analysis and payback period of two green buildings in Turkey. The excess cost of construction observed for both the gold and the platinamount-certified buildings was 7.43% and 9.4312, respectively. It stated that the soft cost percentage on the total construction cost came out to be 0.84% and 1.31%. The reduction in cost for the annual energy consumption came to 31% and 40%. Moreover, payback period for the additional construction cost was calculated to be0.41 and 2.56.

The Article, "LEED Credit Review System and Optimization Model for Pursuing LEED Certification," by Jin Ouk Choi, Ankit Bhatla, Christopher M. Stoppel, and Jennifer S. Shane deals with the inclusion of construction sustainability to achieve desirable building attributes and a project life cycle. One of the authors has developed one supporting tool for the LEED integrative process during a charrette and another one regarding the optimization model which can help project teams decide about which credits to pursue for the certification of LEED. This tool helps project teams make the right green building decisions for their projects through an integrated procedure. The 2009 LEED rating system speaks of six categories: sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, and innovation in design. The authors' model and the supporting tool could capture benefits coming from any LEED credit. As a result, it should lead to lower resource use, better environmental performance, and healthier and more productive use of the built workspace. The authors hope that their works will help federal agencies, institutions, and local governments to optimize sustainability in their design and construction of new projects [33]

"Minimizing Upgrade Cost to Attain LEED Certification for Existing Buildings" by Moatassem Abdallah, Khaled El-Rayes, and Liang Liu A large number of buildings are evaluated for aging and need to be urgently upgraded to achieve better operational, economic, and environmental performance. Building owners often desire to make their construction greener and gain certification under a green building rating system such as LEED. It introduces a new optimization model that reduces costs for upgrades based on achieving a certain level of LEED certification, either Silver or Gold [34]. The model shall set a direction in identifying cost-effective measures and a plan that will achieve the required LEED certification, keeping at a low level the costs for the required upgrades. In the model, problem searching is done using a genetic algorithm.

It efficiently and accurately models optimization problems with a minimum number of decision variables and constraints. This was done with the help of a case study on the building of a rest area. It contributed to the development of a new methodology used to select building upgrade measures to achieve LEED certification in existing buildings at the least cost.

According to "Optimization model for the selection of materials using a LEED-based green building rating system in Colombia" [35] by Daniel Castro-Lacouture and Jorge A. Sefair, buildings are key players in causing environmental impacts due to large carbon emissions and vast usage of resources and energy. The green building movement seeks to lessen these impacts and enhance the construction process for delivering environmental, economic, financial, and social benefits. All these benefits require not only the right technologies but also proper material selection. Inappropriate material selection may be very costly and prevents also reaching environmental goals fixed by a building design. In this paper, a mixed integer optimization model will be presented in order to aid decision makers in selecting appropriate materials. This model is subject to design and budget constraints, maximizing the credits based on the LEED rating system. The case study used for a building in Colombia will be used to explain this, which proposes a version modifying LEED.

"A comparative review of environmental concern prioritization: LEED vs other major certification systems" by Ozge Suzer, presents the prioritization of environmental concern in green building rating importance, globally in use, since it reflects the performance of a building or a development. Some certification systems, although developed nationally, are used worldwide without adjustments for local geographical, cultural, economic, and social parameters. Weighting ends up producing results that are therefore unrepresentative of the region or construction site being evaluated. This paper highlights some issues with weighting environmental concerns using the LEED certification system as a tool originated in the US but used globally. Methodology The methodology of the study involves an analysis of the approach that has been adopted by LEED in two schemes: LEED NC, v.3, and LEED BD + C, v.4; case studies that critique the regional priority credits set up by LEED for four countries—Canada, Turkey, China, and Egypt—based on their local conditions; and undertaking a comparison between major environmental assessment tools like BREEAM, SBTool, CASBEE, and Green Star with LEED. The study brings out the fact that even the latest version, v.4, of LEED has certain shortcomings and inconsistencies in its priorities on the issues of the environment and a sensitivity system for the same. Second, it delineates the approaches the major environmental assessment tools take in respect of this issue and factors to be integrated into future versions of LEED, focusing on the differences and similarities [36].

Finally, "Performance Evaluation of 32 LEED Hospitals on Operation Costs" [37] comments that growing demands in healthcare drive providers to reduce operational costs, which will spur new construction and renovation projects in healthcare facilities during the same time. This makes the environmental impacts of the hospitals bring the healthcare sector into the frontline in terms of the green building movement during the same time. Although many benefits have been posited for sustainable health care facilities, few studies have really been able to prove these benefits. In this study, the authors developed a benchmarking tool using national cost report data obtained from the Centers for Medicare and Medicaid Services that permits health care facilities to compare their operation and maintenance costs with similar facilities. The researchers then analyzed annual data and compared the annual operation and maintenance costs of 32 hospitals with Leadership in Energy and Environmental Design certification to the median cost for non-LEED facilities, controlling for type, ownership, and location. No evidence was found that getting more LEED credits or having LEED certification in general would reduce operation and maintenance costs for healthcare facilities.

"Risk Management in Green Building: A Review of the Current State of Research and Future Directions" [38] identifies gaps in the GB risk literature and explores tendencies by analyzing 64 relevant studies from 2006 to 2020. It can be observed from the findings that the GB risk topic is somehow at an early stage, developing, and almost limited only to some countries, including Singapore, the USA, Australia, and China. In this study, the following major themes of GB risk studies have been identified and categorized: (1) identification of risk factors in GB project implementation, (2) development of risk assessment models for GB projects, (3) research in specific kinds of GB risks, and (4) study on green retrofit project risks. A comprehensive list of GB risk factors was then provided, which may be a useful reference for industry practitioners and future researchers. Moreover, gaps in current literature were found with regard to the inconsistencies in identifying GB risk factors, investigating the relationship between GB risks and project outcomes, and not exploring cross-country or developing countries. Future directions for research were also provided with the view of enriching the literature.

"A Life Cycle Risk Management Framework for Green Building Project Stakeholders" [39] Construction industry is causing adversely the environment, economy, and society henceforth jeopardizing built environment sustainability. Green building projects are an attempt to redress by promoting specified sustainability goals. However, some risks in green building projects might lead to unfavorable outcomes:. The present study evaluates life cycle risks of GB projects and focuses on the role of stakeholders in managing the relevant risks. In this study, a four-step analysis procedure has been followed that comprises a comprehensive literature review, focus-group discussion, fuzzy analytical hierarchy process (AHP), and fuzzy technique for order preference by similarity to ideal solution (TOPSIS). In the view of expert's opinion, the identified risks are ranked. It is found that the findings ranked the nonexistence of skilled green construction staff, the scarcity and unreliability of green subcontractors and suppliers with regard to requirements specific to GB, and the inflation of green materials prices as being the biggest risks. Since most of the significant risks and related stakeholders have already been recognized, a generic life cycle risk management framework for green buildings is developed in order to analyze them. It is, therefore, expected that this research will reach out to practitioners and project stakeholders in GB for designing more effective and robust risk management frameworks.

The paper "Design optimization of office building envelope based on quantum genetic algorithm for energy conservation" by Yuxing Wang and Chunyu Wei holds a special view in the domain of office building envelope design optimization for the sake of conserving energy. The authors propose a quantum genetic algorithm in this respect to minimize construction costs with regard to satisfying the required energy load by the building envelope. By optimizing the parameters relevant to window area, glass curtain wall ratio, and overall cost, the quantum genetic algorithm turns out to be second-best as compared to traditional genetic algorithms. It is worth mentioning that building energy conservation is pretty significant and, at the same time, requires efficient optimization methods if green building standards are to be achieved. The research therefore by Yuxing Wang and Chunyu Wei has pointed out many steps toward the optimization of office building envelopes for energy conservation. In the process, the quantum genetic algorithm application receives a number of advantages over traditional genetic algorithms with regard to reduction in construction costs and improvement in building performance metrics such as natural ventilation and indoor lighting, and faster convergence speed. It can thus be established that the adoption of state-of-the-art optimization techniques in energy-efficient building design is very important, and its result forms part of the global efforts working toward sustainable and green building practices. [40]

The application of two-shell facades is becoming more widespread day by day all over the world, and different researches have been done regarding this field. The facade of the two shells differs according to the weather conditions of each region, the amount of solar radiation, temperature, wind speed, and duration of solar radiation. The results of this research are compared with other researches in the following.

Table 3.1: Comparison of Researches with the Present Research

Author	Year	Location	Results
Gabay	2014	Israeli	The alternative additional expense ranged from 4% to 12% while the cost effective option fell between 0.12% and 1.33%. The extra cost associated with construction is comparable, to that of nations ranging from 0% to 10%.
Achini	2021	Sri Lanka	According to the study green industrial buildings have been found to be 17% more cost effective, over their lifespan compared to buildings. Despite the construction expenses associated with green industrial buildings (29% higher) the operational and maintenance costs are lower resulting in overall savings of 23% and 15%, throughout the buildings life cycle.
Shabir	2021	Hospital Building	A significant amount of energy expenses, carbon dioxide emissions (CO2) and electricity can be reduced by implementing this method. The advantages of incorporating BIM in these

Author	Year	Location	Results
			projects include an eco friendly design process, improved energy efficiency, enhanced building performance and the availability of design options. The obtained Cronbachs alpha value of 0.822 adds credibility to the findings. This approach has the potential to make future buildings more sustainable and contribute to the promotion of energy structures, in our society.
Foo	2023	Kuala Lumpur	The research also highlights the importance of government incentives, education and raising awareness as tactics to encourage the uptake of eco offices in Malaysia. This study offers perspectives for stakeholders enabling real estate experts and developers to make informed choices and manage finances efficiently. Decision makers can leverage these discoveries to improve government incentives and backing mechanisms, for construction. Ultimately the goal of this study is to offer insights to drive the acceptance of office spaces in Malaysia.
Peresent Study	2024	Iran	Green buildings can change much more than just the architectural revolution; they represent a holistic approach to sustainable development that covers environmental care, economic growth, and social welfare. With the assurance of continuous cooperation, innovation, and dedication, it is hard to achieve the goal of constructing an environment in Iran perfectly suited to nature and promoting human well-being. This research is thus representing the energy consumption of an semi-green office

Author	Year	Location	Results
			building in Tehran, designed with Design Builder.

One of the challenges, in advancing building practices in Iran is the lack of a comprehensive and tailored certification system. While other nations have embraced standards like LEED Iran still lacks a framework for assessing and acknowledging building performance. This gap makes it difficult for developers and investors to aim for sustainability without a benchmark to follow. Additionally the impact of sanctions has limited access to materials and technologies posing a significant barrier to constructing eco friendly buildings. The scarcity of these elements hinders innovation. Impedes the integration of sustainable building practices in the Iranian construction sector.

This research underscores substantial discrepancies in energy efficiency and economic viability between conventional and green office buildings, particularly those incorporating double-skin facades with integrated solar panels. The expected thermal advantage defined by Design Builder , attributed to enhanced insulation and ventilation within the double facade, aligns with previous findings (Wong & Li, 2007) highlighting the superior thermal performance of such systems. Consequently, reduced reliance on mechanical cooling translates to lower energy consumption.

If overall energy consumption reduce by approximately 20% in the double-skin facade model, building's benefit-cost ratio would be higher than 0 and green construction would be advantagabel for us (Nia & Zakeri's 2019) findings on energy-efficient building designs. These energy savings hold particular significance in Iran due to volatile energy costs, offering both environmental and economic advantages.

Although this comparative analysis resulted in a very promising outcome, challenges in implementing green building practices in Iran are not overlooked. The lack of the LEED certification and high cost of green materials because of economic instability slow down progress. These barriers match the findings of Zare & Sadeghian, 2020, about the barriers to green building in developing countries.

Alternative means ought to be explored to enhance the economic viability of green construction in Iran. Government incentives related to energy-efficient designs and locally sourced green materials may reduce costs. Moreover, the adoption of affordable yet sustainable technologies and the employment of locally available materials may make green building practices best suited to the local economic and environmental contexts.

In summary, this research concludes that green construction can play a serious role in reducing energy consumption and improving economic viability for Iranian office buildings, especially when innovative designs such as double-skin façades are used in their construction. It also noted that localized adaptations of global green building standards, and government support, are critical if the country is to have a viable sustainable construction industry.

2.1 Proposed Solutions

Clearly, surmounting the setbacks that most impede building development in Iran will call for a multi-faceted strategy. First, it will be necessary to set up a comprehensive certification system covering the different conditions of climate, building type, and material resources available. Different regions of Iran should have a system that offsets the varying environmental challenges and explores the opportunities for a localized approach in line with climatic conditions and sustainability.

From there, vigorous efforts must be undertaken to scout for sustainable sources of materials and forge collaborations with countries not affected by sanctions. This will be very instrumental in diversifying the supply chain, reducing overreliance on traditional sources of building materials, and allowing more innovative and eco-friendly building materials. Concurrently, research and development activities targeted at local technologies that have been nurtured must be strongly promoted. In this regard, investing in home-grown innovations may let Iran build its capabilities and lessen its reliance on foreign technologies bound by geopolitical constraints.

The government may also promote the adoption of green building practices through policy, incentives, and regulations. Providing a framework that encourages investment in sustainable construction could build interest from developers and builders to take a shift toward greener practices in the building industry. This could include financial incentives, tax breaks, or subsidies for implementing green technologies and practices.

It is possible for Iran to overcome such challenges and achieve a more sustainable and resilient built environment by applying these strategies. The green building concept is increasingly getting popular in Iran, but the research landscape has substantial gaps. Most studies target the theoretical framework and concepts rather than case studies or practical implementations. There is a dearth of in-depth case studies that would investigate the performance of green buildings within the Iranian context in order to provide the needed amount of empirical evidence for a case to be made for greater adoption.

To this end, only a few studies probe the financial implications of such projects, notably regarding the costs versus benefits of these projects in green buildings. The lack of such understanding is thus a major hindrance towards mass adoption of green practices since any potential stakeholders remain vague about the economic viability of any such move. Secondly, the contribution of government rules and laws, as well as various incentives, towards improving the growth of green buildings in this country remains unexplored, leaving another vital avenue open for research. This will involve a critical assessment of the policies in place and their effectiveness, and also new regulations that potentially might help in the adoption of green buildings. Most of the research in this area conducted in Iran has failed to address social and cultural aspects of the green buildings, such as the behavior of occupants in these current spaces and the extent to which these innovations are accepted. These gaps should be addressed before the move forward into actual green building initiatives in Iran and formulation of effective policies. Only then will there be developed an understanding of the multi-faceted nature of green building practices and pave the way toward a built environment that is both economically and socially sustainable. The gaps in research have to be systematically filled so that Iran will establish itself as a regional leader on sustainable development, making an example for other.

3. HYPOTHESIS

This study posits that integrating eco-friendly design elements and advanced technologies into office building construction will substantially curtail energy consumption and operational expenses compared to conventional office structures. To test this hypothesis, two distinct office building models—a traditional design and a double-skin façade solar panel semi-green design—were developed using Design Builder software and simulated under Tehran, Iran's climatic conditions. It is anticipated that if the double-skin façade model will exhibit could reduce nearly 18% of energy consumption (mostly related to cooling energy energy in office buildings) and improved indoor environmental quality, it will show the green construction feasibility in Tehran and ultimately enhancing occupant well-being and productivity.

3.1 Rationale

The selection of office buildings as the focus of this research is justified by their considerable energy consumption and consequential impact on urban sustainability. The International Energy Agency (IEA, 2022) underscores the significance of commercial buildings, including offices, in global energy consumption, accounting for approximately 30%. Given Iran's high electricity demand and economic constraints imposed by sanctions, the energy performance of office buildings holds particular relevance. Previous research by Zare and Sadeghian (2020) suggests that optimized design strategies can yield substantial operational cost savings, up to 40%, in office buildings.

While the financial benefits of green buildings, such as reduced operating costs and increased property values, are well-documented, their implementation in Iran faces unique challenges. The absence of LEED certification due to sanctions and the elevated cost of sustainable materials hinder the widespread adoption of green building practices. Consequently, this study emphasizes the necessity of developing tailored local policies and alternative certification frameworks to foster the transition towards sustainable office buildings within Iran's economic context.

In conclusion, this research hypothesizes that green buildings offer both environmental and socio-economic advantages, even in challenging contexts like Iran.

4. CASE STUDY

The design-builder tool was utilized in this investigation to develop two separate concrete design office structures to evaluate energy consumption. The first building is a traditional 3 story office building, whereas the second one is built by the green construction standard with green concrete. The construction of the buildings in Tehran, Vanak has been completed. The location of the environmentally friendly construction project was selected because of its proximity to public transportation.

Table 1 shows the specifications of a concrete building designed in DESIGN BUILDER software. It can be seen that the length of the building is 6 meters, the width of the building is 5 meters, and the height of the building is 10 meters. The specifications of the solar cell used in this building are also shown. Thickness of the transparent solar panel is 0.008 m, the width of the solar panel is 1 m and the length of the solar panel is 1.5 m.

Table 4.1 : Specifications of the Building and Solar Panels Considered

Quantity(m)	Parameter
6	Length
5	Width
10	Height
1	Solar cell width
1.5	Length of the solar cell
0.008	Thickness of the solar cell
1.1	Louvre width
0.45	Louver length
0.4	The depth of the airflow cavity
0.6	Wall-Window ratio

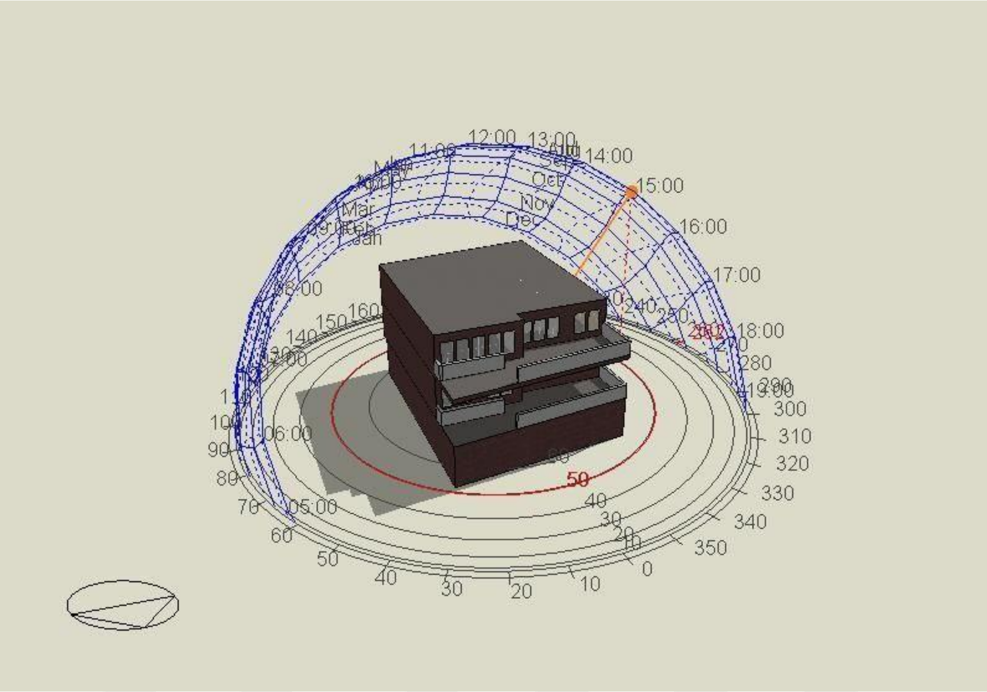

Figure 4.1 : The building designed with two shells in the design-builder software

Figure 4.2 : Building's Design

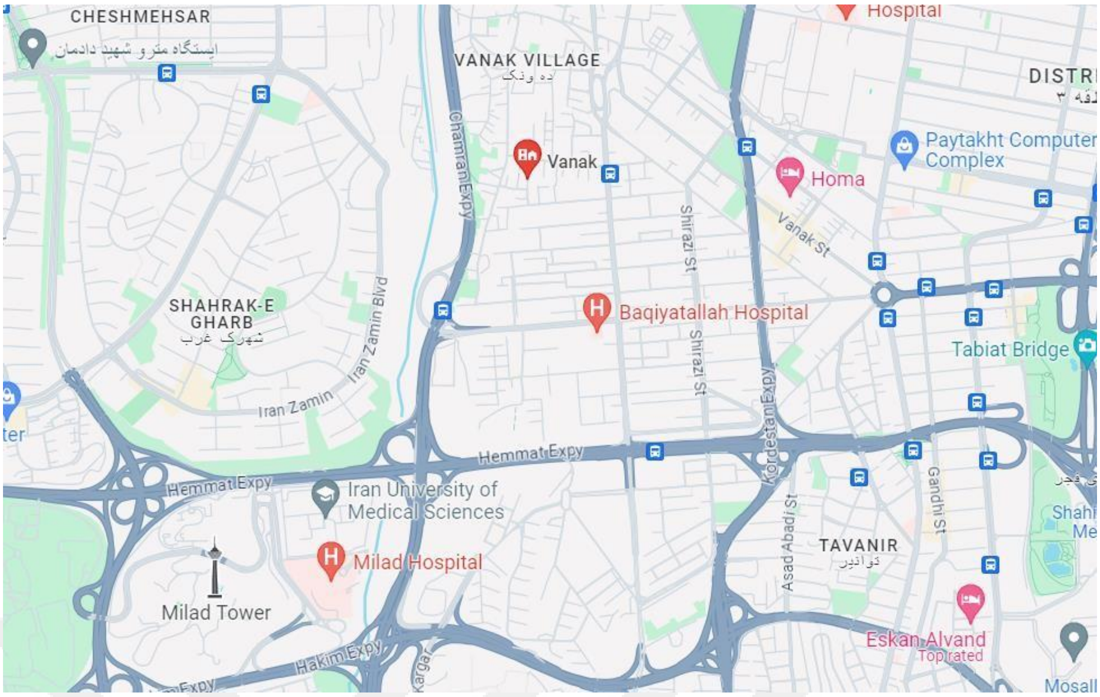

Figure 4.3: Vanak, District 3, Tehran

Figure 4 shows the amount of atmospheric pressure, wind direction, wind speed, amount of direct radiation, amount of diffused radiation, dew point temperature outside the building, and dry bubble temperature outside the building. It can be seen that in the cold seasons of the year, the dew point temperature outside the building is below zero degrees and in the hot seasons of the year the dew point temperature is above zero degrees. Also, the dry bubble temperature outside the building is around 25 degrees Celsius in the hot seasons, and the temperature is between 4 and 10 degrees Celsius in the cold seasons.

The wind speed reached its highest value in May for Tehran, which is 3.8 meters per second. Also, the lowest wind speed in September, October, and November is 1.5 meters per second.

Atmospheric pressure reaches its lowest value in August, which is 87 KPa, and the highest atmospheric pressure occurs in January, November, and December, which is 88 KPa.

The amount of solar radiation in the summer season has its highest amount, i.e. 150-kilowatt hours, which shows the suitable potential of Tehran for using solar cells, and the lowest amount of solar radiation occurs at the beginning of the year, which is equal to 70 to 80 is kilowatt hours.

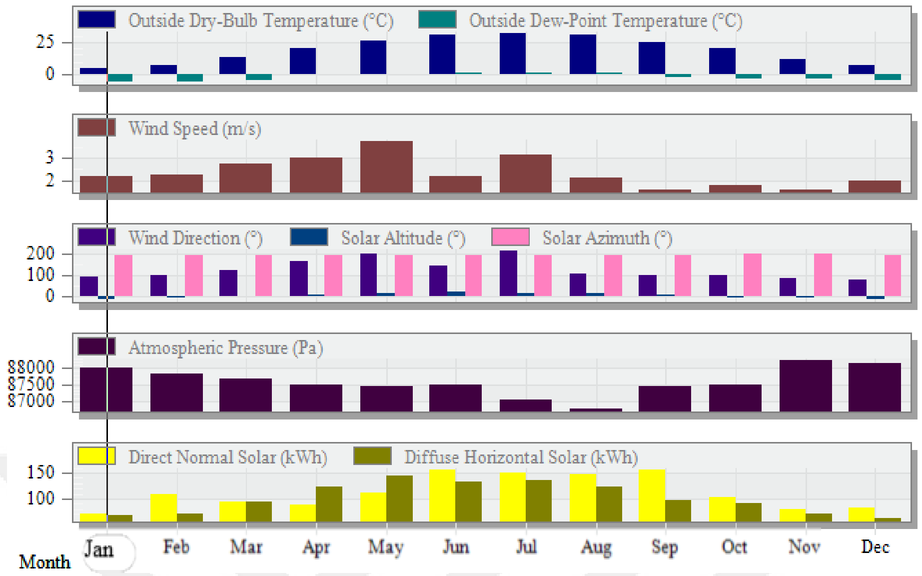

Figure 4.4 : Weather information of Tehran city

In Figure 5, the temperature inside the building is shown in the case of using the two-shell facade and in the case of not using the double-skin facade. It can be seen that if the two-shell facade is used in the building and according to the modeling results, the average temperature inside the building is 2 degrees lower than the case without using the two-shell facade. Sometimes, in the cold seasons of the year, this temperature difference will reach up to 3 degrees Celsius. This diagram shows that the facade of two shells has more heat transfer than the use of building materials such as brick and plaster.

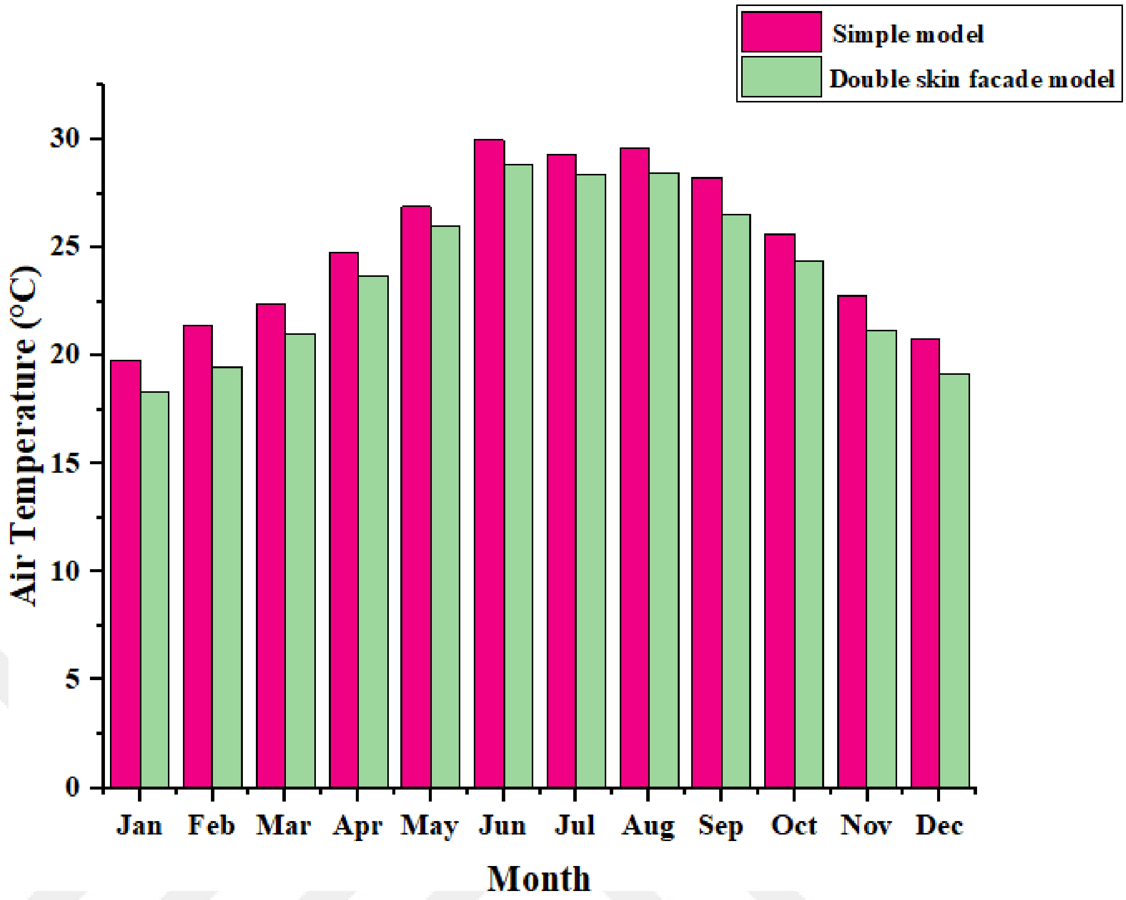

Figure 4.5 : The internal temperature of the building using the two-shell view and the simple Mode

In Figure 6, the amount of illumination inside the building is shown for the two cases of using two skins and without using two skins. It can be seen that in all the months of the year, the amount of lighting inside the building is higher with the use of two-shell facades, which is one of the advantages of using two-shell facades. On the other hand, the facade of two shells can pass a part of the light, but in the simple case, the light cannot pass through the wall of the building, so the facade of two shells will increase the lighting of the building.

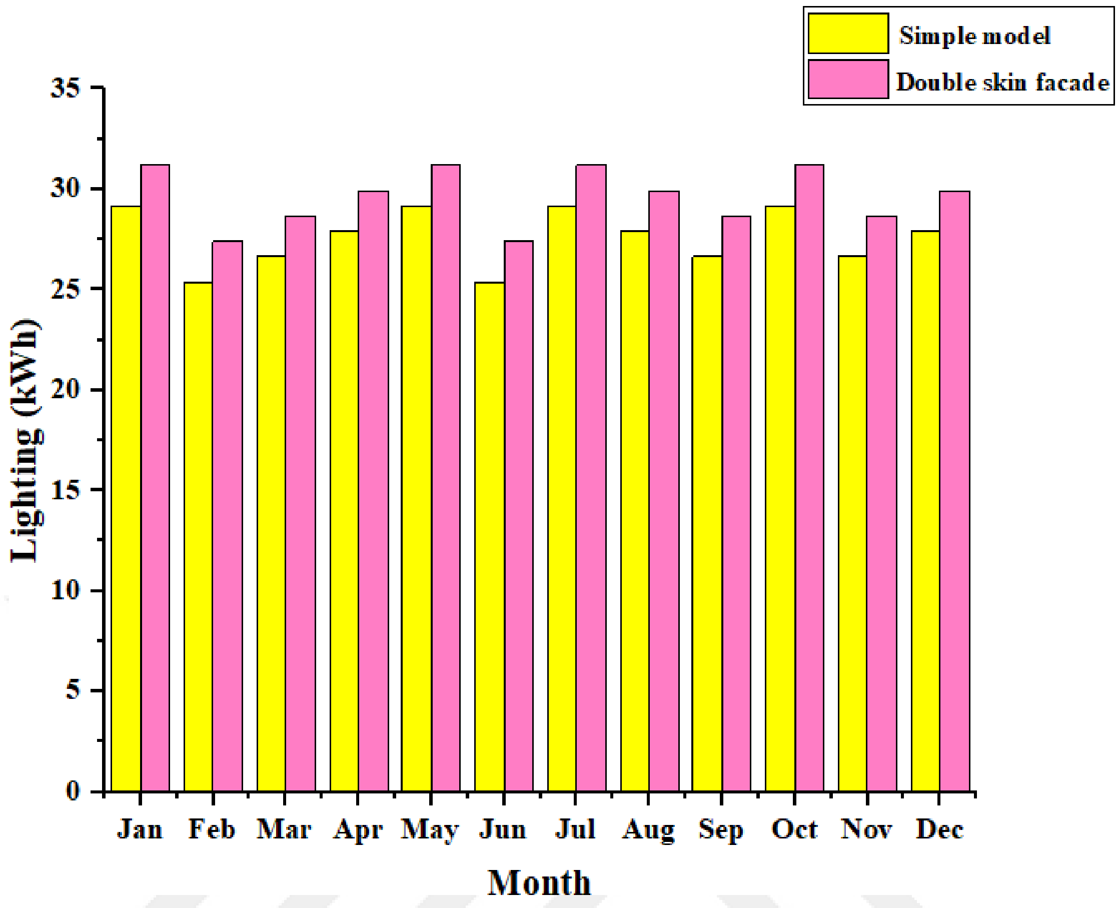

Figure 4.6 : Lighting diagram inside the building in two-shell and simple view mode

In Figure 7, the graph of the amount of cooling consumption of the building is shown in terms of different months for the two cases of two skin facades and without the use of two skin facades. It can be seen that according to the modeling results, the amount of cooling consumed inside the building in most months of the year, except January, July, and August, in the case of using the two-shell facade is less than the simple case. In summer, due to the intensity of solar radiation suitable for Tehran city and the lighting of the facade of the two skins, the temperature inside the building rises and the need for more cooling is needed for proper air conditioning inside the building. In general, it can be said that the facade of two shells has a positive effect on the cooling consumption of the building.

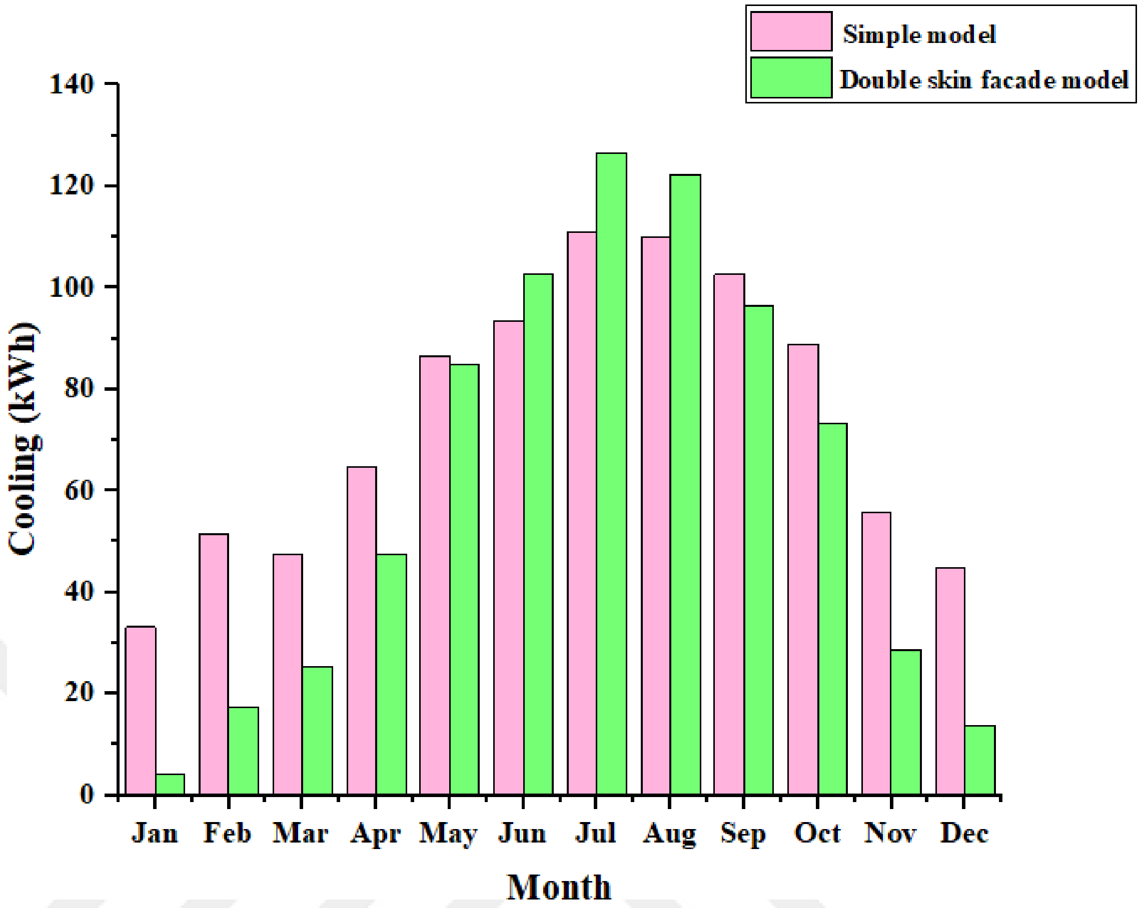

Figure 4.7 : Cooling diagram according to different months of the year

In Figure 8, the amount of electric energy production is shown by the view of two shells (transparent solar cells). By using transparent solar cells, on average, 30-kilowatt hours of electrical energy can be produced every month. In addition to the intensity of solar radiation, solar cells are also dependent on the direction of radiation and the temperature of the environment for the production of electrical energy, and an increase in the temperature of the environment will decrease the amount of electrical energy production. On the other hand, the maximum amount of electric energy production in February, September, and October reaches 40 kilowatt hours. On the other hand, the lowest amount of electrical energy production is in June, which is equal to 25 kilowatt hours.

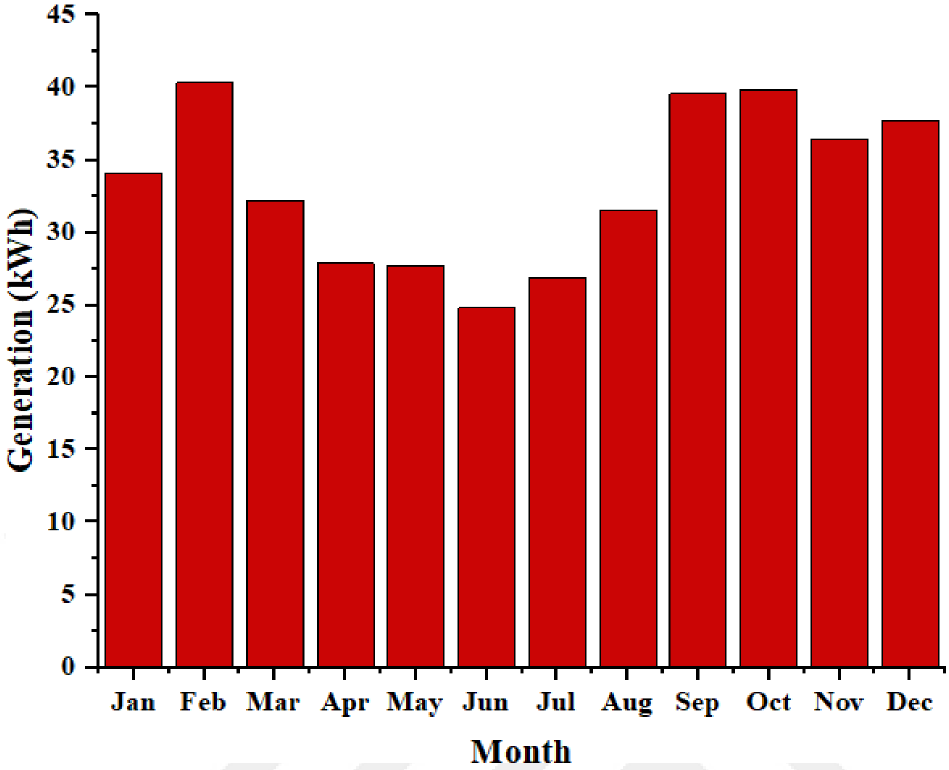

Figure 4.8: Diagram of the amount of electrical energy produced by transparent solar cells

Figure 9 shows the electricity consumption diagram of the building using the two-shell view and without using the pipe-shell view. It can be seen that the electricity consumption in July and August is more compared to the case without using the two-shell facade, but in other months of the year, the electricity consumption of the building is less. The main electricity consumption of the building is related to cooling and heating systems, and because the facade of the two skins allows part of the sunlight to pass through it, more cooling is needed in the summer seasons to provide ideal air conditioning conditions.

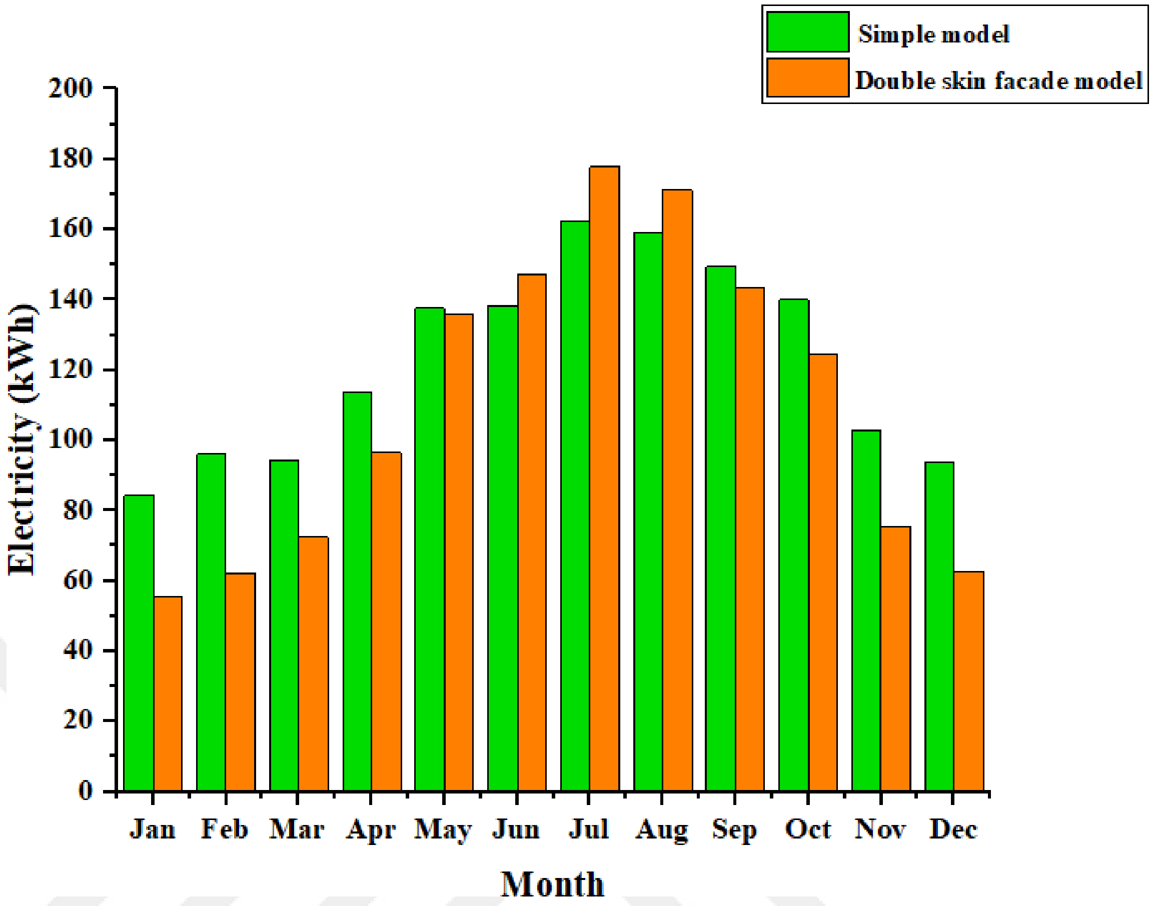

Figure 4.9 : Efficiency graph using two-shell view and simple mode

In Figure 10, the gas consumption diagram of the building is shown for two cases of using a two-shell facade and without using a two-shell facade. Due to the structure of the two-shell facade compared to the use of building materials, the amount of gas consumed by the building using the two-shell facade is much lower than the case without using the two-shell facade, especially in the winter and cold season. Also, the highest gas consumption is in January.

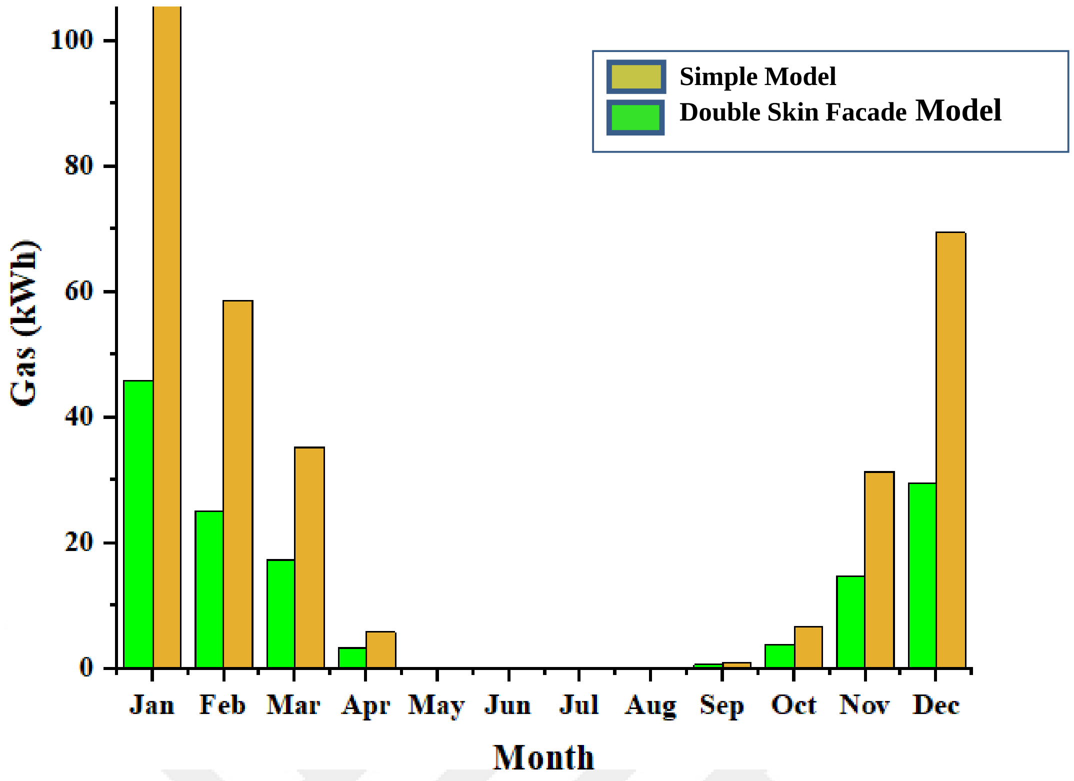

Figure 4.10 : The diagram of the amount of gas consumed by the building using the two-shell facade and without using the two-shell façade

Figure 11 shows the graph of carbon dioxide emissions using the two-shell view and without using the two-shell view. The use of two skin facades with the production of electrical energy using solar cells will provide a part of the electrical energy consumed by the building and on the other hand, reduce the electrical energy consumption from the national electricity grid. As a result, less fuel is consumed in power plants to produce electrical energy, which will reduce emissions.

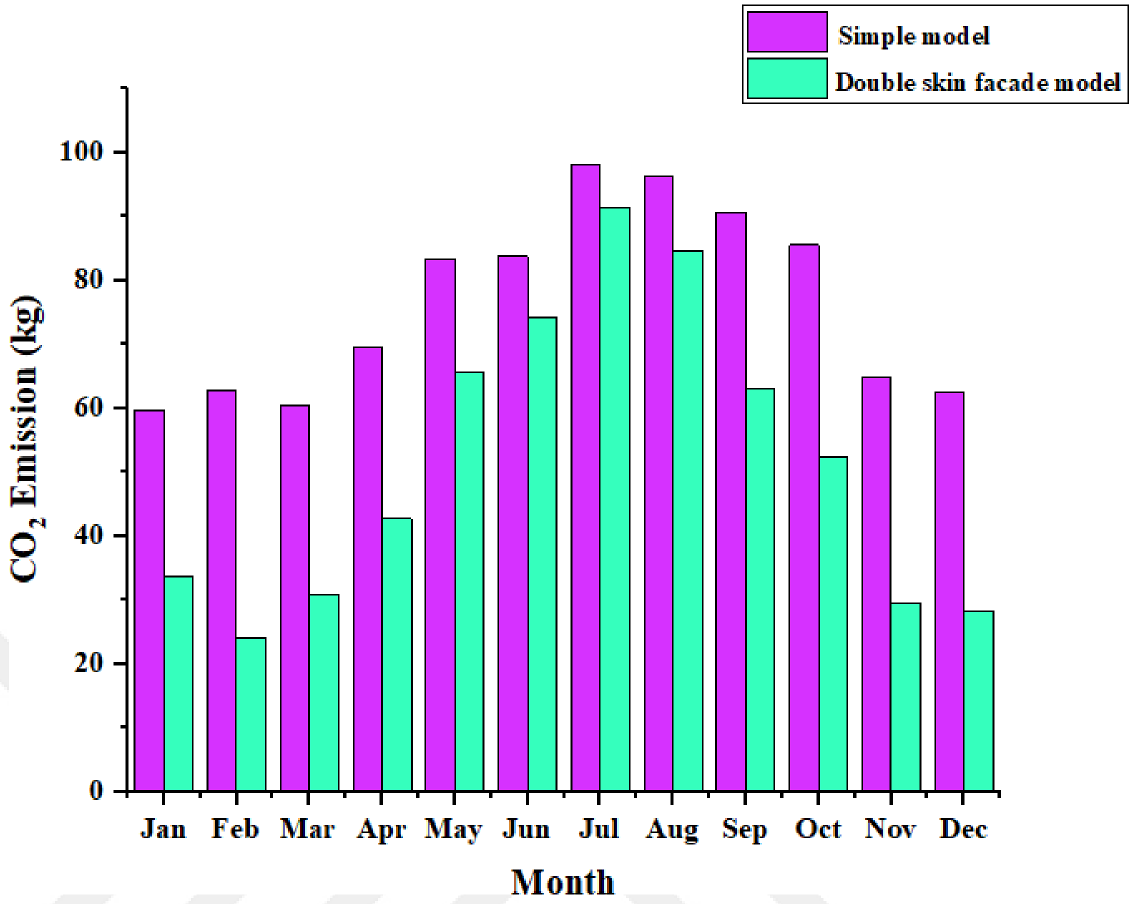

Figure 4.11: Graph of the amount of carbon dioxide emissions using the two-shell view and without using the two-shell view

While double-skin façades are not a new concept, their use is increasingly popular among architects and engineers, especially in skyscrapers. These façades are valued for their transparent appearance and ability to provide thermal and sound insulation, reduce air conditioning costs, and eliminate the need for window-specific technologies. They are also highly adaptable to different weather conditions. By making minor adjustments, such as opening or closing inlet or outlet vents or using air circulators, the façade's performance can be modified.

In cold climates, the air buffer acts as a barrier to prevent heat loss. The sun-warmed air in the cavity can heat the exterior spaces, reducing the need for indoor heating.

In hot climates, the cavity can be ventilated to the outside to reduce solar gain and lessen the cooling load. This is achieved through the chimney effect, where the warmer air rises and escapes, creating a slight breeze and isolating the interior from heat gain.

As the temperature in the cavity increases, the air is pushed out, thus helping to cool the building.

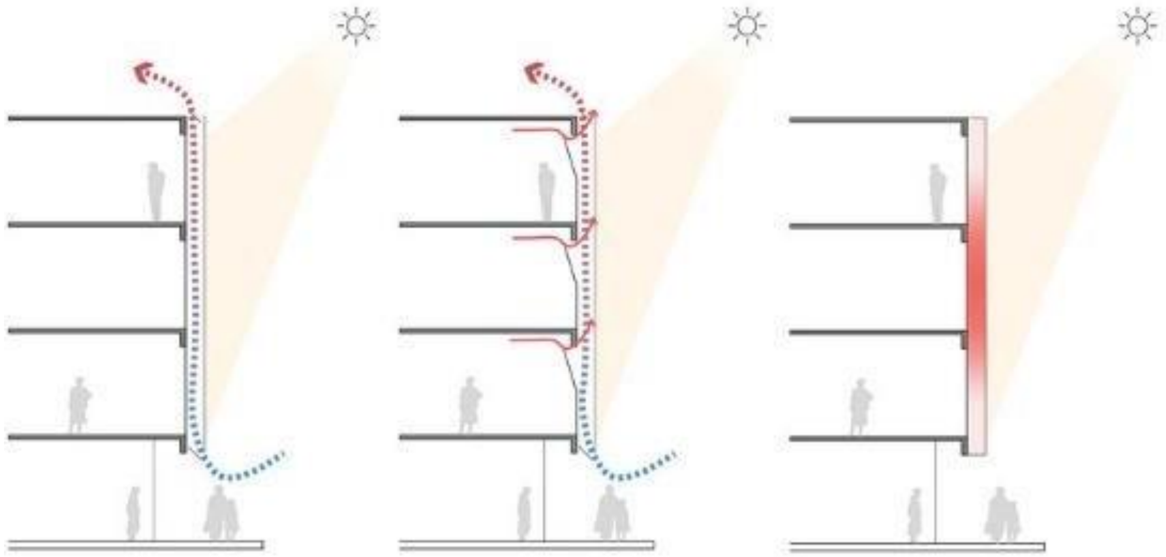

Figure 4.12 : Double Skin Façade

4.1 Discussion

According to the prioritization results from the amount of cost generated from energy consumption of carriers in Iran (2024) in the case study, the cost-benefit ratio analysis method was investigated and implemented.

Table 4.2: Benefit - Cost (Real Calculations)

Action	Initial cost	Annual benefits	Energy saving percentage	NPV (20%)	NPV (26%)	NPV (40%)	PP	BCR
DOUBLE SKIN FAÇADE	437.500.000	11.314.958.4	50%	32.530.259.143,7	28.662.875.262	22.137.410.875	5	25,86
SOLAR PANNELS	437.500.000	9.051.966.67	40%	25.762.528.618,7	22.699.729.550	17.531.851.762	5	19,69
UNDERFLOOR HEATING SYSTEM	89.062.500	9.051.966.67	40%	87.107.796.756,2	76.751.915.962	59.278.380.850	5	101,64

NPV= Net Present Value (Rial)
PP = Payback Period (year)
BCR= Benefit-Cost Ratio

Actions taken for constructing a semi-green office buiding designed by Design builder are shown in the table above. The table shows however LEED certified buildings cannot be registeered in Iran, by taking actions like designing doubke skin façade or solar panels (high cost actions) or designing indoor underfloor heating system and use of argon gas in the middle space of windows(low cost actions) an environmental friendly building can be constructed in existing conditions.

This research calculations 50% of energy conumption could be achieved in 5 years pay back period by using double skin façade. Considering 3 different interest rates of 20%, 26% and 40% construction's benefit-cost ratio is higher than zero that means that this method has economic justification.

Also 40% of energy conumption could be achieved in 5 years pay back period by using 12 solar pannles on the roof (1m*1.5m) . Considering 3 different interest rates of 20%, 26% and 40% construction's benefit-cost ratio is higher than zero that means that this method has economic justification.

Rehabiliants well being is also an important feature in green constructions. Electrical underfloor heating system could provide both occupants well being and economic benefits. 40% of energy conumption could be achieved in 5 years pay back period by impekemnting this design . Considering 3 different interest rates of 20%, 26% and 40% construction's benefit-cost ratio is higher than zero that means that this method has economic justification.

The presented data provides compelling evidence for the economic viability and environmental benefits of implementing green building strategies in a semi-green office building context, particularly in regions with similar constraints to Iran. The analysis of double-skin facades, solar panels, and underfloor heating systems has demonstrated the potential for significant energy savings and positive financial returns.

It is essential to note that the absence of a LEED certification system in Iran presents challenges in quantifying the overall green performance of the building. However, the selected strategies, such as the double-skin façade, solar panels, and underfloor heating, represent effective steps towards creating a more sustainable and energy-efficient office environment.

The case study of the Vanak office building in Tehran illustrates that green buildings can set a precedent for sustainable development. It would contribute to the greater shift towards environmentally sensitive construction practices through huge potential energy savings and proving the project's economic viability.

5. CONCLUSION

With increasing temperatures, leading to climate change, and energy crises facing the world today, there is an emerging need and requirement to rationalize energy consumption within buildings, which remain major consumers of fossil fuels. As a result, environmentally sustainable building construction has become very important.

Green buildings offer an effective solution to help overcome these issues as they consume a considerably lesser amount of energy. The national and organizational mandates for green building are various and thus: the fast-depleting reserves of fossil fuel, rising energy prices worldwide, the need to conserve the environment, and the rapid industrialization of developing countries, which raised competition and consequently, energy demand. Moreover, the rapid movement on a global scale towards renewable sources of energy makes green building practices even more important.

A fundamental distinction between green buildings and conventional structures lies in the integration of advanced, environmentally friendly technologies and materials. These technologies enhance energy efficiency, leading to reduced energy consumption and lower utility costs, thereby providing a substantial return on investment. Although non-renewable energy consumption in Iran is predominantly driven by residential and commercial sectors, the integration of renewable energy sources into high-rise buildings has been less pronounced.

An analysis conducted using Design Builder software found substantial disparities in energy use, electricity utilization, lightening and carbon dioxide emissioin between Green office buildings and conventional ones. This research findings shows that the air temperature in double-skin façade office building is 3% lower than the traditional one. İlluminiation in the second model is 9% higher. Cooling consumption of Simple model is 20% higher. The main percentage of electricity consumption of office buildings is depending on electricity consumption. Thus, double skin façade model comsumes lower electricity than the traditional model about 23%.

Also gas consumption and CO_2 emission of the traditional model is about 2 times of the green office building.

Table 5.1 : Results

	Traditional Construction	Green Construction
Air temperature	3% higher	
. Illuminiation		9% higher
Cooling		20% higher
Electricity consumption		23% higher
Gas consumption	95% higher	
Co2 emission	64% higher	

Green construction techniques not only enhance energy efficiency but also prove to be cost-effective in the long term. Buildings designed with sustainable practices, such as double-skin façades, solar panels, and smart energy management systems, reduce energy consumption significantly and minimize operational costs.

Also these constructions showcase outstanding performance, showcasing the efficacy of sustainable design principles in decreasing resource use and cutting operational expenses over the building's lifecycle.

Given three interest rates of 20%, 26%, and 40%, the project's Net Present Value was evaluated. The results showed a positive NPV in all scenarios, suggesting that the project is financially justified.

Green Construction in Iran can bring enormous transformation, far more than a simple development in Architecture; it suggests holistic growth towards sustainability with regards to environmental care, economic development, as well as social welfare. Because of continuous collaboration, innovation, and commitment, achieving the envisioned constructed environment in harmony with nature and society, providing well-being for all, is at hand.

5.1 Recommendations:

The combination of factors has hindered the full diffusion of building management systems (BMS) in existing buildings within Iran. There has been a general lack of comprehensive campaigns for raising awareness, and few specialized companies dealing with green building retrofits have paid attention to BMS.

But energy subsidies provided by the government have only exacerbated the situation. Assuming that a good deal of energy is going to get wasted during a building's lifetime, developers have been unwilling to bear upfront costs. The result is traditional, less efficient systems still prevail in buildings. Inability of property purchasers to absorb the pro-rated cost of a smart building management system has also discouraged the developers from undertaking such projects.

Depending on several studies, BMS can offer savings up to 70% in energy use. Deeper coverage of BMS implementation in existing buildings is therefore an area for future research, with topics such as cost-benefit analyses, occupant behavior, and integration with other building systems. This study has focused on gas and electricity, overlooking its water consumption. With water becoming a scarce commodity in the future, it may be appropriate to consider the efficiency of potable and non-potable water supplie from onsite wells. Related economic reasons for separation between potable and non-potable water supply systems may also be explored.onsite wells. Related economic reasons for separation between potable and non-potable water supply systems may also be explored.

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