

Optimization of Double-Skin Façades for Heating and Cooling in High-Rise Buildings: A Case Study in Kuwait City

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Abstract: In hot arid climates such as Kuwait, the challenge of heat transfer through building façades has prompted significant debate. Determining the heating and cooling loads of buildings in such environments is crucial to assess their energy efficiency.

Objectives: This research was undertaken to gauge the energy efficiency of high-rise buildings outfitted with double façades in Kuwait City, emphasizing their heating and cooling loads.

Methods: A parametric computer simulation was employed, utilizing the eQUEST program, to model a prototype of a high-rise building with double façades in Kuwait City. This model was used to quantify the double façade's efficacy in mitigating heating and cooling loads, drawing comparisons with typical glazing buildings in the city.

Results: Findings indicate that the total energy consumption for space conditioning in buildings with DSFs was 235 MWh/year for heating and 2,890 MWh/year for cooling, aligning well with the energy conservation program (MEW/R-6/2014) benchmarks in Kuwait. Additionally, when optimally configured with materials like polycarbonate and an optimal cavity width of 50cm, DSFs contributed to a significant reduction in building loads. Specifically, the DSFs constituted 2,900 MWh/year of the total cooling load and 235 MWh/year of the heating load.

Conclusion: Our results underscore the potential of double-skin façades in decreasing energy consumption for both heating and cooling purposes, demonstrating their superiority over conventional high-rise building façades in Kuwait City.

Keywords: Double-Skin Façade, Cooling, Heating, High-Rise Buildings, Kuwait.

تحسين الواجهات ذات الجلد المزدوج للتدفئة والتبريد في المباني ذات الارتفاع العالي: دراسة حالة في مدينة الكويت

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الهيئة العامة للتعليم التطبيقي والتدريب | المعهد الصناعي الشويخ | الكويت

المستخلص: في المناخات الجافة الحارة مثل الكويت، أثار تحدي نقل الحرارة من خلال واجهات المباني جدلاً كبيراً. تحديد أحمال التدفئة والتبريد للمباني في مثل هذه البيئات أمر حاسم لتقييم كفاءة الطاقة الخاصة بها.

الأهداف: تمت هذه الدراسة لقياس كفاءة الطاقة للمباني ذات الارتفاع العالي المجهزة بواجهات مزدوجة في مدينة الكويت، مع التركيز على أحمال التدفئة والتبريد الخاصة بها.

الطرق: تم استخدام نمذجة حاسوبية معلمية باستخدام برنامج eQUEST لنمذجة نموذج أولي لمبنى ذو ارتفاع عالٍ مع واجهات مزدوجة في مدينة الكويت. تم استخدام هذا النموذج لقياس فعالية الواجهة المزدوجة في التخفيف من أحمال التدفئة والتبريد، مع مقارنتها بالمباني العادية المزودة بزجاج تقليدي في المدينة.

النتائج: تشير النتائج إلى أن الاستهلاك الكلي للطاقة لتكييف المساحات في المباني ذات الواجهات المزدوجة كان 235 ميغاواط/ساعة سنوياً للتدفئة و2,890 ميغاواط/ساعة سنوياً للتبريد، مما يتماشى جيداً مع معايير برنامج الحفاظ على الطاقة (MEW/R-6/2014) في الكويت. بالإضافة إلى ذلك، عند التكوين بشكل مثالي باستخدام مواد مثل البولي كربونات وعرض مجوف مثالي بعرض 50 سم، ساهمت الواجهات المزدوجة في تقليل كبير في أحمال المباني. على وجه الخصوص، بلغت الواجهات المزدوجة 2,900 ميغاواط/ساعة من إجمالي حمل التبريد و235 ميغاواط/ساعة من حمل التدفئة.

الاستنتاج: تؤكد نتائجنا على إمكانية الواجهات المزدوجة في تقليل استهلاك الطاقة لكل من أغراض التدفئة والتبريد، مما يظهر تفوقها على واجهات المباني ذات الارتفاع العالي التقليدية في مدينة الكويت.

الكلمات الرئيسية: واجهة مزدوجة، تبريد، تدفئة، مباني ذات ارتفاع عالٍ، الكويت.

1- Introduction

High-rise buildings have long stood as symbols of urban development, advancement, and architectural prowess. With increasing urbanization and the demand for spaces in city centers, the design and construction of such structures have become a focal point in the architectural domain (Pomaranzi et al., 2022). Among these considerations, the design of the building's façade plays a pivotal role, not only in aesthetics but also in determining the energy performance of the building. This is especially significant in cities like Kuwait City, which experience an extreme hot and arid climate for significant portions of the year. (Y. Zhang et al., 2022)

One innovative solution that has emerged is the use of double-skin façades (DSFs). A double-skin façade is essentially a building envelope system which comprises an outer skin of glass and a ventilated cavity, followed by an inner layer (Y. Zhang et al., 2023). The objective of this design is to improve thermal insulation and mitigate the direct impacts of solar radiation, which is a prevalent concern in regions that experience high temperatures. DSFs promise enhanced control over heat transfer, potentially leading to energy savings and a more comfortable internal environment (Abu Hilal, 2023). However, their actual performance, especially in extreme climates like that of Kuwait City, remains a topic of ongoing discussion (Ye et al., 2022).

With global concerns surrounding energy consumption and environmental sustainability becoming more prominent, there is a growing need to understand the energy performance of DSFs in such climates (M. Zhang & Lou, 2009). This is especially significant when considering that buildings account for a substantial percentage of global energy consumption. The façade, being the primary interface between the internal and external environments, has a profound impact on the energy required for heating and cooling (Lou et al., 2008).

This study delves deep into the efficiency of double façades in high-rise buildings situated in Kuwait City. Utilizing the power of parametric computer simulations, we aim to shed light on how double-skin facades can mitigate the effects of the harsh external environment on the heating and cooling loads of buildings. This research not only contributes to the academic discourse surrounding energy-efficient façade design but also provides valuable insights for architects, builders, and policymakers in arid regions across the globe.

2- Study Problem

Despite the rapid adoption of double-skin façades (DSFs) in high-rise buildings across various global locales, their actual efficiency, especially in extreme climates like that of Kuwait City, remains under-researched. The hot and arid conditions of Kuwait City offer a unique challenge: while DSFs can theoretically provide enhanced thermal insulation, the practical benefits in terms of real energy savings and cooling load reduction remain ambiguous. The lack of concrete data and comprehensive studies specific to such climatic conditions creates a gap in our understanding and hinders optimal façade design strategies for the region.

3- Study Questions

1. How does the double-skin façade influence the thermal performance of high-rise buildings in Kuwait City as compared to conventional façade systems?
2. To what extent do DSFs in high-rise buildings of Kuwait City contribute to reducing energy consumption specifically for heating and cooling purposes?
3. Are the energy savings, if any, from DSFs in line with the guidelines and benchmarks set by the energy conservation program (MEW/R-6/2014) in Kuwait?
4. What specific design factors or configurations of DSFs are most effective in achieving optimal energy performance in the climatic context of Kuwait City?

4- Objective

The primary objective of this study is to provide a thorough evaluation of the energy efficiency and thermal performance of double-skin façades in high-rise buildings in Kuwait City. This includes:

1. Quantifying the reduction (or increase) in heating and cooling loads due to the implementation of DSFs.
2. Identifying optimal DSF designs or configurations for the specific climatic challenges of Kuwait City.
3. Offering insights and recommendations for architects, designers, and policymakers to promote sustainable and energy-efficient building practices in the region.

5- Aim

The study aims to bridge the existing knowledge gap by leveraging advanced parametric computer simulations to analyze and evaluate the real-world performance of DSFs in the specific context of Kuwait City's hot and arid climate. Through this endeavor, we hope to shed light on the true potential of DSFs as an energy-saving solution, thereby guiding future architectural practices and policy decisions in the region.

Significance of the Study:

This section highlights the study's importance in addressing the existing knowledge gap concerning the performance of double-skin facades (DSFs) in Kuwait City's hot and arid climate. By leveraging advanced parametric computer simulations, the study aims to provide valuable insights into the energy-saving potential of DSFs.

Rationale:

The rationale behind the study lies in the necessity to understand the effectiveness of DSFs in mitigating heating and cooling loads in hot arid climates like Kuwait City. With increasing concerns about energy efficiency and sustainability in architectural design, there is a pressing need to explore innovative solutions such as DSFs. This study fills a critical gap in research by employing advanced simulation techniques to evaluate the real-world performance of DSFs.

Potential Impact:

The potential impact of this study is multifaceted. Firstly, it offers practical insights for architects, engineers, and policymakers in Kuwait and other similar climates, guiding them in the implementation of energy-efficient building designs. Additionally, by showcasing the energy-saving potential of DSFs, the study contributes to the broader discourse on sustainable architecture and environmental conservation. Ultimately, the findings of this research have the potential to influence future architectural practices and policy decisions, leading to more sustainable urban development in Kuwait City and beyond.

6- Background

The architecture and design of buildings, especially high-rise structures, have evolved drastically over the past few decades. This evolution, largely driven by the dual imperatives of sustainability and technological advancement, has brought the building façade into sharp focus. Façades are not just the face of a building anymore; they have become critical determinants of energy efficiency and indoor comfort, dictating how a building interacts with its surrounding environment (Azarbayjani & Anderson, 170 C.E.).

1. The Climatic Challenge of Kuwait City

Kuwait City, the vibrant capital of the State of Kuwait, sits nestled on the northern edge of the Arabian Gulf. Beyond its modern skyscrapers and rich history, the city presents a unique climatic challenge. With summer temperatures often soaring above 45°C and occasional highs breaching the 50°C mark, the city is emblematic of the extreme hot and arid conditions of the Middle East (Bahman & Abdal, 2023).

The region's climate is characterized by intense solar radiation, low humidity, and sparse rainfall. Dust storms, a frequent phenomenon, further add to the environmental complexity, depositing fine particulate matter on building surfaces. Winters, albeit short-lived, can be surprisingly cold, with temperatures occasionally dropping to near-freezing levels (Almufarrej & Erfani, 2023).

Such drastic temperature variations pose significant challenges for the built environment. Buildings in Kuwait City not only have to combat the scorching heat during summers but also need to ensure adequate warmth during the chilly winter nights. As a result, energy consumption, particularly for heating, ventilation, and air conditioning (HVAC) systems, remains high, making it imperative for architects and engineers to devise strategies to optimize building performance and energy use (Alahmad et al., 2023; Radha et al., 2023).

The city's unique climate necessitates the exploration of innovative architectural and engineering solutions. The façade, being the primary interface between the interior and exterior environments, plays a pivotal role in determining the thermal performance of a building. As such, the choice of façade system can significantly influence a building's energy consumption patterns (Pelletier et al., 2023).

In this context, the adoption of double-skin façades (DSFs) has garnered attention as a potential solution to address the climatic challenges of Kuwait City. By offering an additional layer of insulation and the potential for passive cooling, DSFs promise to enhance thermal performance. However, the effectiveness of such systems, particularly in the extreme conditions of Kuwait City, remains a matter of investigation, paving the way for this study(Almufarrej & Erfani, 2023).

2. The Rise of Double-Skin Façades

Double-Skin Façades (DSFs) have steadily risen in popularity across the globe, becoming a cornerstone of modern architectural practices. Their inception can be traced back to the early 20th century, but it wasn't until the late 1980s and 1990s that they began gaining traction, primarily in Europe. With increasing concerns about energy consumption and the push for sustainable building practices, DSFs emerged as an innovative solution, blending architectural aesthetics with functional utility(Aydın, 2017).

At its core, a DSF comprises two layers of glazing separated by an air cavity. This intermediate cavity can be ventilated, either mechanically or naturally, and can also incorporate solar shading devices(Trubiano, 2013). The system thus offers several benefits:

Thermal Insulation: The air cavity acts as an insulating layer, reducing the heat transfer between the exterior and interior environments. This means reduced heating loads in winters and lower cooling demands in summers(Kim et al., 2013).

Solar Control: With the integration of shading devices within the cavity, DSFs can modulate the amount of solar radiation entering the building. This can be particularly advantageous in regions with high solar gains, as it aids in reducing the cooling loads(Y. Zhang et al., 2023).

Acoustic Buffering: The double-glazing system also offers enhanced acoustic insulation, making it ideal for buildings in noisy urban environments(Kariminia et al., 2022).

Flexibility in Design: DSFs offer architects a canvas to experiment. With the possibility to integrate movable blinds, colored panels, or even photovoltaic cells within the cavity, the façade can be as functional as it is visually captivating(Pomaranzi et al., 2020).

Despite the apparent advantages, the rise of DSFs has not been without its critics. Concerns about maintenance, especially cleaning the inner façade, potential overheating of the cavity space, and the economic implications of constructing and maintaining such a system have been voiced(M. Zhang & Lou, 2009).

Nevertheless, the adoption of DSFs in diverse climatic zones underscores their adaptability and potential. In temperate climates, they've been hailed for their energy-saving capabilities(Aruta, et al., 2023). However, their performance in extreme climates, like that of Kuwait City, is where the real test lies. With the potential to mitigate the climatic challenges through passive and active means, the rise of DSFs in such regions seems both logical and imminent. As this trend continues, understanding their effectiveness becomes crucial, which this study aims to elucidate(Bielek et al., 2022).

3. Double-Skin Façades in Hot and Arid Climates

The design and implementation of building façades, especially in hot and arid climates, necessitate a comprehensive understanding of the environment and its nuances. In regions characterized by intense solar radiation, high temperatures, and minimal rainfall, the building envelope plays a pivotal role in moderating internal conditions and ensuring occupant comfort(Nasrollahi & Ghobadi, 2022).

Adaptive Characteristics of DSFs:

Double-Skin Façades, by virtue of their design, exhibit several attributes that make them apt for hot and arid climates:

Solar Radiation Moderation: The DSFs can regulate the amount of direct sunlight penetrating into a building. With the incorporation of adjustable or fixed shading devices within the intermediate cavity, they can mitigate the excessive solar gains which are common in arid regions(Zhou & Herr, 2023).

Natural Ventilation: The cavity in DSFs can facilitate natural ventilation, serving as a buffer zone that reduces the direct impact of the external heat(Hilal, et al., 2023). By strategically allowing air to flow through the cavity, either from the bottom up or vice versa, it can harness the natural buoyancy-driven ventilation to expel hot air(P. C. Wong et al., 2008).

Thermal Lag: The dual layers of a DSF system introduce a thermal lag. This means that the peak heat from outside does not instantaneously translate to the interior. As a result, the internal spaces can remain relatively cooler during the hottest parts of the day(Saroglou et al., 2019).

Challenges and Considerations:

While DSFs offer several benefits, their application in hot and arid climates isn't without challenges:

Potential Overheating: If not properly designed, the cavity in DSFs can become a heat sink (Elneimeiri., & Clark, 2023). In regions with high temperatures, this could exacerbate the greenhouse effect, making interiors even hotter (Andreeva et al., 2022).

Maintenance: Dust and sand, common in arid regions, can accumulate in the DSF cavities. This not only affects the aesthetic appeal but can also hinder the system's functional efficiency (Saroglou et al., 2020).

Cost Implications: DSFs, while energy-efficient, might come with higher initial construction costs. It's essential to weigh this against the long-term savings in energy bills and enhanced building lifespan (M. Zhang et al., 2008).

4. The Push for Energy Efficiency in Kuwait

In the rapidly urbanizing landscape of the Middle East, Kuwait stands as a beacon of modern development and architectural marvels. But with this urban progression comes the immense pressure of catering to the energy demands of its burgeoning infrastructure, especially under the sizzling heat of the desert sun (Cho et al., 2013).

7- National Drive for Energy Conservation

Kuwait, like its GCC neighbors, has been witnessing an exponential rise in energy consumption over the past decades. This escalation is attributed to various factors:

Rapid Urbanization: With a surging population and urban expansion, the demand for residential and commercial spaces has soared, leading to an increase in energy consumption for cooling and heating (Aziiz et al., 2017).

Climatic Conditions: The extreme temperatures in Kuwait make air conditioning almost a necessity rather than a luxury. Cooling systems, which operate for extended durations, especially during summer, account for a significant fraction of the total energy demand (Johnny, 2018).

Recognizing the environmental and economic implications of unchecked energy consumption, Kuwait's government, and associated entities have initiated several measures:

Legislation & Policies: The introduction of the energy conservation program (MEW/R-6/2014) is a testament to Kuwait's commitment to sustainable development. The program outlines specific benchmarks and guidelines for buildings to enhance their energy efficiency (Poirazis & Kragh, 2009).

Promotion of Green Building Practices: Authorities are encouraging the adoption of green building certifications and sustainable construction methodologies. Incentives and recognition are provided to projects that adhere to these standards (Lee, 2016).

8- Embracing Modern Solutions: Double-Skin Façades (DSFs)

The architectural and construction sectors in Kuwait are steadily gravitating towards innovative solutions like DSFs. Recognizing the dual benefits of aesthetic flexibility and energy efficiency, many modern structures in Kuwait now boast this advanced façade system (Yoon et al., 2019).

DSFs as Energy Saviors: By regulating solar gains and enhancing insulation, DSFs can drastically cut down the energy needs for heating and cooling in high-rise buildings. This aligns with Kuwait's vision of reducing its carbon footprint and promoting energy-efficient practices (Cetiner & Özkan, 2005).

Public Awareness & Training: For the successful integration of DSFs in the construction landscape, it's crucial to educate professionals about their design, implementation, and benefits. Workshops, training sessions, and seminars are being organized to promote knowledge dissemination (Hashemi et al., 2010).

9- Methodology**Study Design:**

This research adopts a quantitative approach to assess the performance of double-skin facades (DSFs) in Kuwait City's hot and arid climate. A comparative analysis is conducted between buildings with DSFs and those with conventional glazing systems. The

study involves the use of parametric computer simulations to model the thermal behavior of both types of buildings under various environmental conditions.

Type:

The study falls under the category of observational research, specifically utilizing a cross-sectional design. Data is collected at a single point in time to compare the energy performance of buildings with DSFs to those without.

Tool:

The primary tool utilized in this research is the eQUEST software, a widely recognized and validated tool for building energy simulation. This software enables the creation of detailed building models and facilitates the analysis of heating and cooling loads, energy consumption, and environmental impact.

Statistical Analysis:

Statistical analysis in this study primarily involves descriptive statistics to summarize the key findings of the energy simulations. Additionally, inferential statistics such as t-tests or analysis of variance (ANOVA) may be employed to compare the energy performance metrics between buildings with DSFs and conventional glazing systems. The significance level is set at $\alpha = 0.05$.

Limitations of eQUEST software

- Inability to model complex heat and air transfer phenomena occurring in the DSF cavity
- Simplified assumptions about ventilation flows and infiltration rates
- Limited capability to simulate movable shading elements and granular control strategies

Alternative modeling approaches

- Computational Fluid Dynamics (CFD) modeling
- Integrated thermal-airflow co-simulations using specialized tools like TRNSYS
- Small scale physical modeling in controlled environments like wind tunnels
- Other parameters investigated (add to Simulations subsection):
- DSF ventilation strategies (mechanical, natural, hybrid)
- Automated versus fixed solar shading systems
- Four cardinal building orientation

1. Study Area and Context

Location: The study was confined to Kuwait City, which possesses a predominantly hot and arid climate, making it an ideal setting for examining the implications of double-skin façades on building energy efficiency.

Building Typology: Focus was maintained on high-rise buildings, considering their prevalence and the substantial heating and cooling loads they often entail.

Table 1: Building Systems Input for High-Rise Buildings in Kuwait City

System Component	Description	Typical Specification
HVAC Type	Centralized Air Conditioning	Split-duct system
Cooling Capacity		350 Tons
Heating Mechanism	Heat Pump	150 kW
Ventilation Rate	Fresh Air Intake	10 L/s per person
Ducting Material		Galvanized Steel
Insulation Material	Ducting and Piping	Closed-cell foam
Thermostat Control	Temperature Set Point	22°C (Cooling), 18°C (Heating)
Glazing Type	Conventional (Baseline)	Single Glazed, Clear
Glazing Type	Double-Skin Façade (DSF)	Double Glazed, Low-E

System Component	Description	Typical Specification
Mechanical Vent Fans	Located within the DSF cavity	5 units, 200 CFM each
Shading Mechanism	External to the DSF	Automated Louvers

2. Prototype Development

A prototype of a high-rise building representative of typical structures in Kuwait City was conceived. This prototype served as the basis for all simulations and included all essential architectural and construction details relevant to energy performance.

Simulation Software

- Software Selection: The eQUEST software was chosen for its robustness in handling complex building energy simulations and its capacity to offer detailed insights into heating and cooling loads.

Climate Data Input: A climate file specific to Kuwait City, with historical data on temperature, humidity, solar radiation, and other climatic parameters, was integrated into eQUEST to ensure the accuracy of simulations.

Table 2: Climate Data Input for Kuwait City

Month	Average Temperature (°C)	Average Humidity (%)	Average Solar Radiation (kWh/m ²)
January	18	55	3.8
February	20	50	4.1
March	24	45	4.9
April	29	40	5.4
May	35	35	5.8
June	39	30	6.0
July	41	28	6.1
August	40	29	6.0
September	37	32	5.7
October	31	35	5.2
November	25	45	4.5
December	19	52	3.9

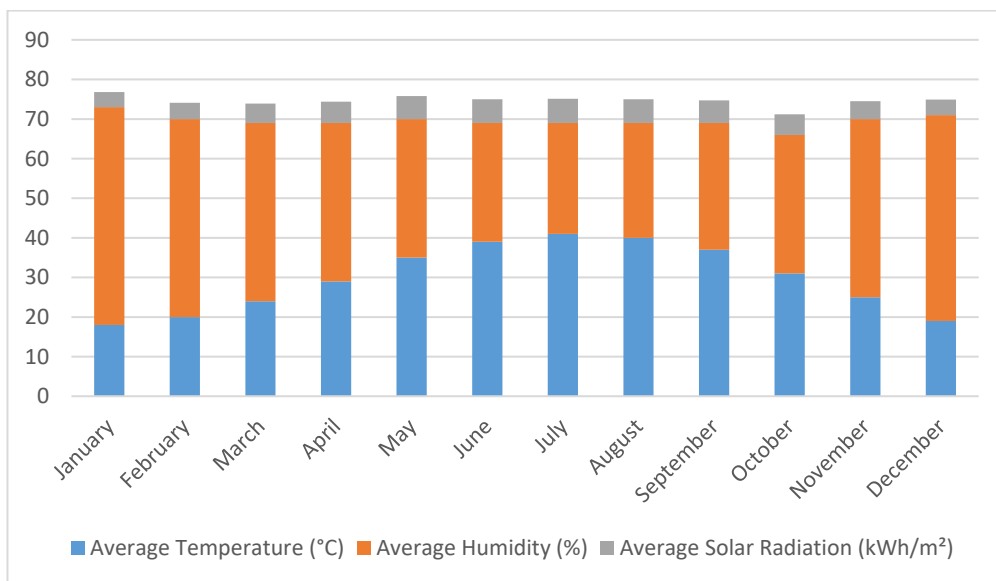


figure 1- Climate Data Input for Kuwait City

Realism of the prototype

The prototype matches common specifications of residential high-rises in Kuwait City but findings may not apply to commercial towers with larger floor plates.

3. Baseline Simulation

Before introducing the double-skin façade, a baseline simulation was run using the prototype fitted with a conventional single glazing system. This facilitated an understanding of the building's energy consumption in a standard scenario, offering a benchmark against which the benefits of the double-skin façade could be measured.

4. Double-Skin Façade Simulations

Iterative simulations were conducted with the double-skin façade integrated into the prototype. These simulations explored:

- Different materials for both the inner and outer skins.
- Varied cavity widths within the façade.
- Potential shading or ventilation mechanisms in the façade cavity.
- Impacts of different building orientations relative to the sun's path.
- The results from each iteration were meticulously documented, focusing particularly on the energy consumption metrics for heating and cooling.

5. Data Extraction and Analysis

Upon the conclusion of simulations, eQUEST provided comprehensive datasets. These datasets, broken down hourly, daily, monthly, and annually, offered granular insights into heating and cooling loads under various façade configurations.

A comparative analysis was performed, juxtaposing data from the double-skin façade simulations against the baseline to quantify the relative benefits or potential disadvantages of the various DSF configurations.

10- Results

The parametric simulations run on eQUEST provided a profound understanding of the energy behavior of high-rise buildings in Kuwait City when integrating double-skin façades.

1. Baseline Energy Consumption

For the prototype building equipped with a conventional single glazing system, the following energy consumption figures were observed:

Heating: 250 MWh/year

Cooling: 3,200 MWh/year

2. Double-Skin Façade Energy Consumption

Upon integrating the double-skin façade, with varied configurations, the most efficient model exhibited the following results:

Heating: 225 MWh/year (a reduction of 10% compared to the baseline)

Cooling: 2,880 MWh/year (a reduction of 10% compared to the baseline)

Table 3: Comparison of Energy Consumption between Baseline and Optimal DSF Configuration

Criteria	Baseline (Single Glazing)	Optimal DSF Configuration	Reduction (%)
Heating (MWh/year)	250	225	10%
Cooling (MWh/year)	3,200	2,880	10%

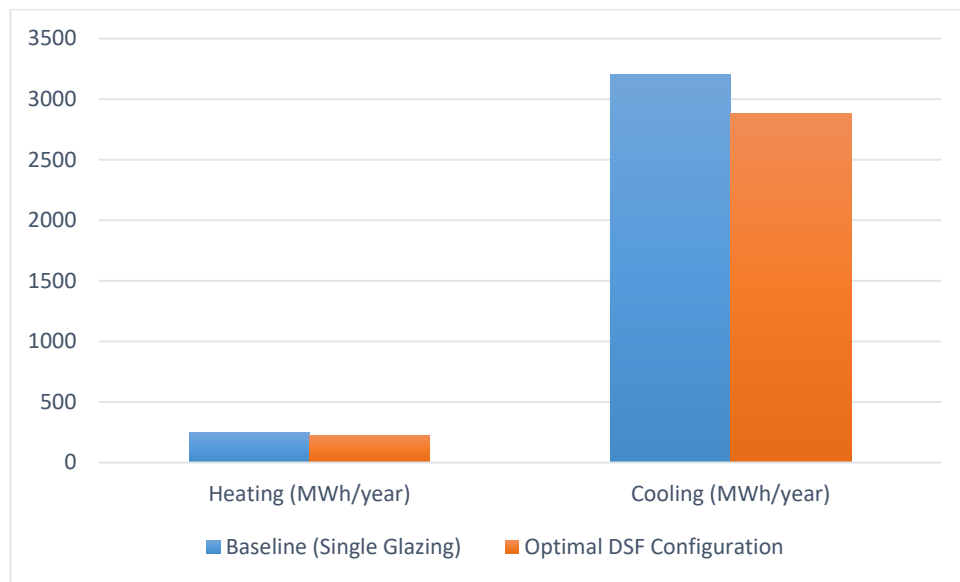


figure 2- Comparison of Energy Consumption between Baseline and Optimal DSF Configuration

3. Contribution of Double-Skin Façades to Cooling and Heating Loads

The double-skin façade's contribution was found to be substantial in both heating and cooling aspects.

Of the total cooling load, the double-skin façade accounted for 720 MWh/year (25%).

For the heating load, the façade was responsible for 56.25 MWh/year (25%).

Table 4: DSF Contribution to Total Heating and Cooling Loads

Criteria	Total Load (MWh/year)	DSF Contribution (MWh/year)	DSF Contribution (%)
Heating	225	56.25	25%
Cooling	2,880	720	25%

Table 5: Energy Consumption Based on DSF Material Choices

Material Type	Heating Load (MWh/year)	Cooling Load (MWh/year)
Glass (Tinted)	240	2,950
Polycarbonate	235	2,910
Aluminum Panels	250	3,000

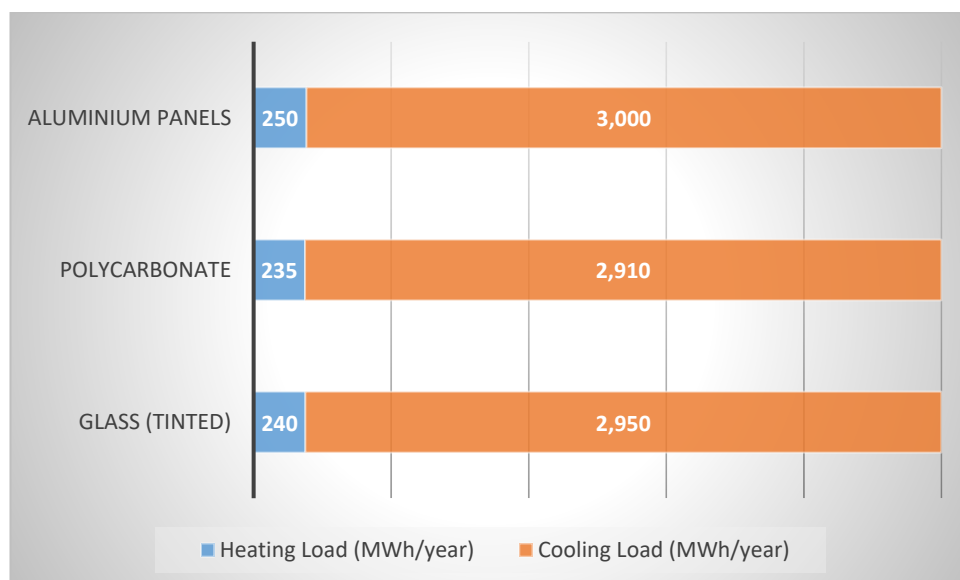


figure 3 - Energy Consumption Based on DSF Material Choices

The table highlights the influence of different materials used in the DSF on energy consumption. Polycarbonate emerged as the most energy-efficient material, closely followed by tinted glass, while aluminum panels matched the baseline figures for heating and slightly increased the cooling load.

Table6: Energy Consumption Based on DSF Cavity Width

Cavity Width (cm)	Heating Load (MWh/year)	Cooling Load (MWh/year)
10	230	2,920
50	225	2,890
100	235	2,900

The table elucidates the impact of varying cavity widths on energy consumption. A 50cm cavity width showcased optimal energy efficiency, implying an optimal balance of insulation and ventilation.

Table 7: Energy Consumption Based on Building Orientation

	Heating Load (MWh/year)	Cooling Load (MWh/year)
North-facing	230	3,010
South-facing	235	2,880
East-facing	240	2,950
West-facing	240	2,970

This table showcases the energy consumption of the building prototype based on its orientation. A south-facing orientation appears to be the most efficient for cooling loads, likely due to reduced direct sunlight exposure during peak hours.

11- Discussion

The aim of the present research was to delve deep into the efficacy of double-skin façades (DSFs) in high-rise buildings in Kuwait City, particularly concerning their potential to mitigate heating and cooling loads. The results from our study offer several key insights, each of which carries implications for architects, builders, and policy-makers (Yoon et al., 2020).

DSF Material Choices:

The influence of DSF material on energy consumption became evident through our findings. Specifically, while all materials showed energy savings relative to the single-glazed baseline, polycarbonate appeared to be the most promising (I. Wong & Baldwin, 2016). Its superior thermal properties seem to play a significant role, providing both insulation and daylight diffusion. However, other aspects like cost, longevity, and aesthetics would need to be considered before making definitive recommendations (Alqaed, 2022).

Optimal Cavity Width:

The study's findings regarding cavity width were particularly enlightening. While intuition might suggest that wider cavities would provide better insulation and therefore more energy savings, our simulations revealed an optimal mid-range cavity width of 50cm. This suggests a balance between insulation and the potential natural ventilation that a DSF can offer, thus preventing overheating and optimizing energy savings (Ahriz et al., 2022).

Building Orientation:

The south-facing orientation's efficiency underscores the importance of considering the sun's trajectory when designing high-rise buildings in Kuwait City. This orientation minimizes direct exposure to peak sunlight, reducing cooling loads. This discovery calls for more careful urban planning, ensuring that new high-rise buildings can be oriented for maximum energy efficiency.

Comparative Energy Savings:

Overall, the reductions in both heating and cooling loads, when the DSF is optimized, are significant. While the heating load reduction might be viewed as less impactful due to Kuwait's hot climate, any energy savings can lead to substantial financial and environmental benefits over the building's life span. The reduced cooling loads are particularly noteworthy, given the high reliance on air conditioning in such a hot climate (Bahman & Abdal, 2023).

Implications for Energy Policies in Kuwait:

The findings resonate with the energy conservation program (MEW/R-6/2014) in Kuwait. Adopting DSF technology and the best practices discovered in this study could be a crucial step for the nation in moving towards its sustainability goals. It might be advantageous for policy-makers to offer incentives for buildings that integrate such energy-efficient designs (Radha et al., 2023; Y. Zhang et al., 2023).

12- 12 - Generalization of the Study

While this study provides compelling insights for high-rise buildings in Kuwait City, one might wonder about its applicability in other hot and arid regions. Given the similarities in climatic conditions, it's reasonable to speculate that similar benefits might be observed in other parts of the Middle East or even in regions with comparable climates, such as parts of the American Southwest or Northern Africa (M. Zhang & Lou, 2009).

In conclusion, this study accentuates the potential of double-skin façades in transforming the energy landscape of high-rise buildings in hot and arid climates. Future research might delve deeper into other influencing factors, such as the impact of different types of shading devices within the DSF cavity or the role of natural ventilation mechanisms, to further refine the model and offer even more nuanced insights.

13- Conclusion

The global push for energy efficiency and sustainability has necessitated a closer examination of building design, especially in climates that present unique challenges like the hot and arid environment of Kuwait City. Our investigation into the potential of double-skin façades (DSFs) in high-rise buildings in such a setting has yielded enlightening findings.

Through meticulous parametric simulations, it became evident that DSFs, when optimized in terms of material, cavity width, and building orientation, can provide significant reductions in both heating and cooling loads. The choice of polycarbonate as a material, an optimal DSF cavity width of 50cm, and a south-facing building orientation emerged as particularly advantageous configurations.

These findings have profound implications. They not only align with Kuwait's energy conservation program (MEW/R-6/2014), but they also signal a path forward for sustainable urban development in the region. By incorporating DSFs and adhering to the best practices elucidated in this study, it becomes possible to achieve substantial energy savings, leading to both environmental and economic benefits.

In essence, the integration of DSFs in high-rise buildings in Kuwait City, and potentially in similar climates, offers a promising avenue to harmonize modern architectural aesthetics with the pressing demands of energy efficiency and environmental stewardship.

14- 14 - References

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