The Impact of Smart Windows on the Energy Efficiency of Office Buildings

By

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Contents

Abstract

This article will focus on reviewing, evaluating, analyzing, as well as concluding several different existing researches and literature on the role different types of smart glasses and especially electrochromic smart glass's role in improving the energy efficiency for buildings. This is because they have different characteristics and properties that make them useful when they are used for energy efficiency of buildings. Since buildings are one of the several energy consuming sections, engineers see an urgent need to take all the measurements to prevent such great energy losses in buildings. Different parts of the building, such as doors, windows, walls, and roofs are vulnerable to heat gain and heat loss. This article will focus on windows which are known to be one of the most vulnerable when it comes to energy losses in buildings. In addition, it is important to note that it can be extremely costly to cool and heat buildings that are poorly adapted to the environments. Therefore, it is the architect's job to improve energy loss by using appropriate building materials and new technology to establish and maintain an appropriate atmosphere inside the building. **The problem** is that the types of window's glass can highly contribute to the reduction of the amount of energy loss in office building. **Aim of this paper** is the role of Smart Glass in improving the energy efficiency for office buildings, and to make certain that electrochromic windows is the best choice out of the three different types of smart windows to be tested then used for office building in Sulaymaniyah. **Hypothesis**: It is suitable to test then use electrochromic smart windows for the office buildings in Sulaymaniyah.

Introduction

The importance of this paper is how smart glass windows in general and electrochromic windows especially help with shaping the buildings. Regardless of the measurements taken, heat loss will continue to occur. However, it is the engineer's job to find the best methods and materials that can largely reduce the amount of energy loss in buildings. According to Ajaz Ahmed, energy crisis has obstructed the economic progress and growth, so efforts are required to produce and use supplies that prevent energy loss (Ahmed, 2014, p. 371). This journal article states that the loss of energy in buildings can highly contribute to the economic destruction due to energy crisis. Therefore, this indicates that every step towards producing and using environmental and economical friendly supplies and materials is crucial. Once the different types of smart glass are evaluated, studied and compared to explain why electrochromic windows should be tested and used in Sulaymaniyah for office buildings. With the technological advancement and use of different types of smart glasses, windows are developed in a way that can efficiently decrease a building's energy losses and demands, meanwhile, improving the indoor environment and atmosphere .

Literatures review

Generally, the use of smart glass in buildings can largely contribute in the energy management of the building as well as the activities of the people inside the building. This is because our bodies are in balance with our surroundings. According to Adam Aston, smart glass or else known as switchable glass can control the type and amount of light that comes into a building, and through this it can control more than energy loss, instead, it can also enhance the physical activities and the mood of the people inside the building (Aston, 2014, p. 1). This journal article shows us the multipurpose and benefits of replacing regular windows with smart glass.

Indeed, it explains how smart glass can do more than saving energy. Therefore, the article explains, when smart glass is used in a working building, it will most likely improve the productivity and output of the employees, further, it is also less costly if we consider everything else, we have to provide for the building in the long run when a regular window is used, such as heating and cooling system, drapes, louvres, and so on (Aston, 2014, p. 1**). By saying this, the article, explains how our activities and mood can change if our body is not in balance with the environment. In addition, it is good how the article mentions the benefits and uses of smart glass in a working building. This is because there are lots of working buildings in Sulaymaniyah as well, and if we were to use smart glass in these buildings, then similar to what the article states, the productivity of the employees will improve alongside saving money and energy**. This article perfectly captures the multiuse of smart glass, and its reasoning's agree with replacing regular windows with smart windows in Sulaymaniyah. This is mostly because the article states that, even though smart glass can be expensive, the money is returned only under 10 years (Aston, 2014, p. 1**). This may sound like a lot of time, but it is actually not when Sulaymaniyah situation is taken into consideration electricity wise. This is because a lot of money need to be paid to provide electricity for the building in order to work the heating and cooling system**

*Figure 1: EC **Smart windows are aesthetically pleasing and comforting,** (Mahdavinejad, Bemanian, Khaksar & Abolvardi, 2011, p. 336**)***

Furthermore, as previously mentioned, there are different types of smart windows. The most used ones and major types are electrochromic smart glass, thermochromic smart glass, and photochromic smart glass. According to Mohammadjavad Mahdavinejad, Mohammadreza Bemanian, Neda Khaksar, Ghazal Abolvardi, Photochromic, which can control glare, reduce transmitted radiation and obstruct UV radiation, change from clear state to transparent colored state only when they are subjected to light or even ultraviolet radiations, further, this type of smart window tends to darken more during winter time in the northern latitudes (Mahdavinejad, Bemanian, Khaksar & Abolvardi, 2011, p. 336**). This article shows exactly why photochromic windows should not be used for office buildings in Sulaymaniyah. This is because Iraq is located in the northern latitudes and winter is the time during which solar heat is most beneficial, therefore, if the photochromic cannot serve its purpose due to the reasoning this article gives then it is best to not choose this type of smart window.**

*Figure 2: **Photochromic smart windows performance during daylight** (smart glass VIP|official page)*

Moreover, according to the same article, Thermochromic windows has low transmissivity in the visual part of the spectrum which can often line up from 27% to 35% (Mahdavinejad, Bemanian, Khaksar & Abolvardi, 2011, p. 2). **Due its low transmissivity as it can also be noticed in the attached picture below, it is not highly suggested.**In addition, according to Siamak Hoseinzadeh, the reason electrochromic windows are better than the other smart glass windows are because they are more efficient when it comes to providing lighting and solar energy (Hoseinzadeh, 2019, p. 155)**. From both of these article reviews, electrochromic windows seem to be the better**

choice when it comes to lighting and solar energy efficiency.

*Figure 3: **Thermochromic smart windows** (Mahdavinejad, Bemanian, Khaksar & Abolvardi, 2011, p. 336)*

In addition, according to Mohammadjavad Mahdavinejad, Mohammadreza Bemanian, Neda Khaksar, Ghazal Abolvardi, Electrochromic smart glass windows are capable of varying through radiant energy by low voltage electrical pulse, further, unlike photochromic smart windows, this type of smart glass can change its shade from clear to fully dark or any other level of tint, and unlike thermochromic smart windows, electrochromic smart windows are largely developed for the reduction of heat transmissivity while remaining transparent (Mahdavinejad, Bemanian, Khaksar & Abolvardi, 2011, p336) **As result, from the review of both articles, we can see that out of these three different types of smart glasses, electrochromic smart window seems to have the right characteristics for office buildings. With this being said, since the performance of these different smart windows are highly affected by weather and climate condition, tests should be conducted to make certain that electrochromic smart window is useful and affective for the climate and weather condition of Sulaymaniyah. certain that electrochromic smart window is useful and affective for the climate and weather condition of Sulaymaniyah. Further, the performance and usefulness of smart glass can change depending on the climate condition of the specific region. Since this report is dedicated to figuring out whether electrochromic smart windows are suitable to get tested in Sulaymaniyah,**

northern Iraq or not, the location and climate condition of this region should be highly considered. According to Janusz Marchwiński, Electrochromic smart windows can perform its best in the east and west of the northern hemisphere (Marchwiński, 2014, p. 1685). **Since Sulaymaniyah, northern Iraq is located in the east of the northern hemisphere, electrochromic smart windows seem to have the right properties for the office buildings in Sulaymaniyah.** In addition, according to Neil L. Sbar, Lou Podbelski, Hong Mo Yang, and Brad Pease**,** electrochromic windows can block solar gain to decrease the load on building air conditioning systems during summer, however, it allows solar gain during the winter which will decrease energy needed to heat the building (Sbar, Podbelski, Yang & Pease, 2012, p. 129). This article states that electrochromic windows are suitable for both climates.

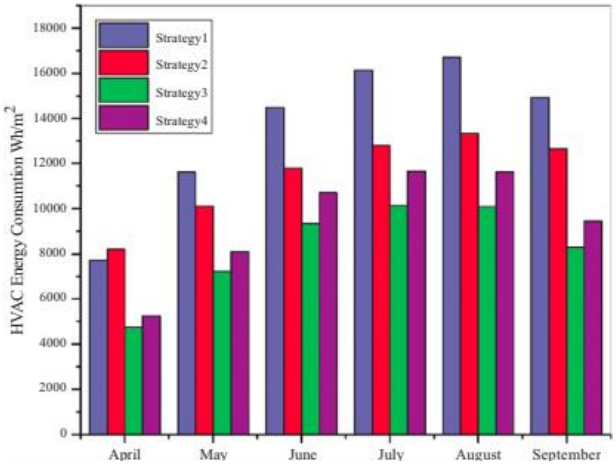

Figure 5: Energy consumption in terms of warm months in different strategies in Yazd (Hoseinzadeh, 2019, p. 159).

Furthermore, according to Siamak Hoseinzadeh, electrochromic smart windows can highly perform during the cold months if the EC windows are set to be non-colored because this way it will minimize the amount of energy needed for heating, however, during summer, the best way is to set the EC windows in colored state in order to gain the maximum result from the energy storage (Hoseinzadeh, 2019, p. 154). Since the other article review already concluded for us that electrochromic windows are the one to get tested for our region. In addition, according to Janusz Marchwiński, "EC glazing requires low-voltage power up to 10 V DC to change their state" (Marchwiński, 2014, p. 1682). **This amount of voltage is extremely low which makes this type more suitable to be tested in Sulaymaniyah. Further, the previous article written by Siamak Hoseinzadeh is dedicated to the performance of EC smart windows in a number of cities in Iran, such as Yazd, Bandar Abbas, and Tabriz. Tabrez climate condition have similar climate condition with Sulaymaniyah. Therefore, from this we can conclude that since they have approved the high performance of EC windows in this region, the same performance can be expected in Sulaymaniyah which is why they should be tested in Sulaymaniyah as well**. For example, according to Siamak Hoseinzadeh, this research paper has conducted the electrochromic smart window research for four different strategies in a number of cities in Iran; the first strategy is a common window, the second strategy is the use of EC windows in (Off mode), the third strategy is the use of EC windows in (On colored mode), and the fourth strategy is adjustment of (On and Off mode) based on temperature variation (Hoseinzadeh, 2019, p. 157-158). **As it can be seen from the graph below, during the warm months, the energy consumption of Yazd is like the following for the four different strategies**

From figure 5, we can conclude that strategy 3, the on mode, is the best strategy for the warm months from April to September. This is because the least amount of energy is consumed compared to the other strategies throughout the warm months in Yazd. Since the weather in Sulaymaniyah is also warm to hot during these months, this strategy may also be practical for Sulaymaniyah. Overall, since these cities in Iran has more warm, dry months compared to wet, rainy months, we can see from the table below that strategy 3 which is the (on colored mode) consumes the least energy out of all four strategies. On the other hand, as it can be seen from (figure 5, figure 6), the common window consumes the most energy.

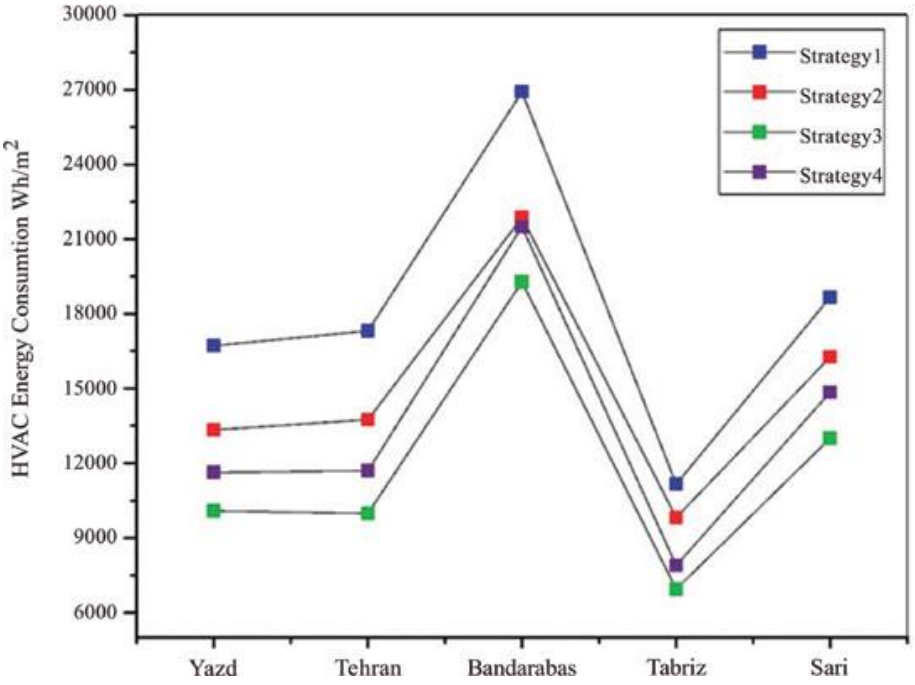

Figure 6: Energy consumption in different climates in four different strategies in August (Hoseinzadeh, 2019, p. 161).

Moreover, it is important to note that strategy four is also performing its best. This is because it's on and off mode is adjustable according to the temperature variation. However, since these cities have a warm to hot climate for most of the months like Sulaymaniyah, strategy 2 which is most suitable for wet seasons is not performing its best overall. From both article reviews, we can conclude that electrochromic smart window may also perform its best in Sulaymaniyah due to its location and long warm-hot, dry seasons, and few rainy months. In order for the electrochromic smart windows to perform its best, (colored mode) should be used during summer, meanwhile, the Off (bright mode) or else known as off-condition should be used during winter and the cold months. This way, we can save the most amount of energy in both different climates in Sulaymaniyah. As a result, electrochromic smart windows can be considered the best choice for Sulaymaniyah city in terms of testing. This is due to its properties as well as performance in similar climate condition. Furthermore, now that we know electrochromic smart windows may

be suitable to be used in Sulaymaniyah, let's take a closer look at the characteristics and properties of this type of smart window and its multipurpose and suitability in office buildings.

According to Neil L. Sbar, Lou Podbelski, Hong Mo Yang, and Brad Pease, **"**Buildings account for ~40% of the world's energy use with the resulting carbon emissions substantially more than those in the transportation sector" (Sbar, Podbelski, Yang & Pease, 2012, p. 126). From this article, we understand that by reducing energy loss in office buildings, we are reducing CO_2 emissions. Another major reason that may make this type of smart glass suitable for office building is their durability property. According to the same article, electrochromic windows are extremely durable and aesthetically pleasing which is why they are considered as good architectural material; they can endure full range of climatic as well as solar conditions, indeed, their life expectancy can exceed 30 years (Sbar, Podbelski, Yang & Pease, 2012, p. 126).In addition, this types of smart glass can prevent glare and optimize daylight which makes it suitable for office building, so the employees can work in a comfortable environment with perfect lighting that is not too strong or too dark. according to Neil L. Sbar, Lou Podbelski, Hong Mo Yang, Brad Peased, "All static glazing systems were assumed to have manual shading devices that are pulled by building occupants when glare becomes uncomfortable" (Sbar, Podbelski, Yang & Pease, 2012, p. 129). From this, we understand that electrochromic windows can prevent glare because of its manual shading device as stated in the article. This is because they can be pulled down manually whenever seemed necessary.

Figure 7: Schematic view of the EC glass section [author], EC smart window during on and off model, (Marchwiński, 2014, p. 1679)

Moreover, according to Siamak Hoseinzadeh, electrochromic windows let sunlight in on cool days, meanwhile, it blocks sunlight during hot days (Hoseinzadeh, 2019, p. 155). With this being said, it helps to maintain perfect lighting at all times during the day regardless of the weather condition. Further, according to Neil L. Sbar, Lou Podbelski, Hong Mo Yang, and Brad Pease, daylight sensor can be used to control the level of tint desired depending on the condition of the sky (Sbar, Podbelski, Yang & Pease, 2012, p. 135).

Meanwhile, in some cases a remote control or a switch is used manually to turn on or off the mode, this article suggests that a daylight sensor should be used which is a new technology that has many benefits for smart windows. According to Janusz Marchwiński, "This type of device has a

long memory once switched (power is not required for three to five days to maintain a given switched state)" (Marchwiński, 2014, p. 1682). This is another major reason that makes these types of smart glass even better than the other ones is that it does not require constant power supply.

Reviewed research	Type of reference	Published year	Titles	Case study	Main findings
Ahmed, A. (2014)	Research paper	2014	Energy Smart Buildings: Potential for Conservation and Efficiency of Energy	Study followed the descriptive analysis method to highlight the energy efficiency and conservation potential of energy smart buildings.	The loss of energy in buildings, its relation to the economic destruction and its importance.
ASTON, A	Journal article	2014	Smart Glass Opens Window of Opportunity	Glass building product that tints automatically can save energy and dollars.	Multipurpose, benefits of replacing regular windows with smart glass
Hoseinzadeh, S. (2019).	Research paper	2019	Thermal Performance of Electrochromic Smart Window with Nanocomposite Structure under Different Climates in Iran.	This research paper has conducted the EC smart window research for four different strategies in a number of cities in Iran like Tehran, Yazd, Bandar Abas, Sari.	Using Yazd's strategy due to its properties and performance in similar climate condition to Sulaymaniyah
Mahdavinejad, M., Bemanian, M., Khaksar, N., & Abolvardi, G. (2011).	Research paper	2011	Choosing Efficient Types of Smart Windows in Tropical Region Regarding to Their Advantages	Focuses on different major types of smart glass windows in tropical regions.	different major types of smart glass windows, and its pros and cons
Marchwiński, J. (2014)	Research paper	2014	Architectural Evaluation of Switchable Glazing Technologies as Sun Protection Measure.	concentrates on architectural evaluation of the application of the switchable glazing technologies as sun protection measures.	EC glazing requires low-voltage power- its suitability to our climate region. similar to what stated
N., Podbelski, L., Yang, H., & Pease, B. (2012)	Journal article	2012	Electrochromic dynamic windows for office buildings.	Focuses EC windows and its benefits to use it in office building.	Using EC windows and its benefits to use it in office building, Its pros and cons.

Conclusion

In conclusion, smart window is a new building technology that has successfully advanced the engineering world. In general, they are environmentally friendly, sustainable, and extremely efficient in saving energy as well as maintaining appropriate atmosphere within the environment. As a result of this article, we have come to realize that out of the most commonly used smart glass windows, electrochromic smart window maybe the best one to be tested for office buildings in Sulaymaniyah, so the result proves the hypothesis to be true. Because of its durability, aesthetic, energy saving, properties in general, and it is especially suitable for Sulaymaniyah weather condition. Further, this type of smart glass does not require constant power supply which is a huge deal especially for a city like Sulaymaniyah since there is always electricity issues. To sum up, this article reviews clearly showed the efficiency of electrochromic glasses for office buildings along with their suitability for the climate and weather condition of Sulaymaniyah. Therefore, they should be tested in Sulaymaniyah in order to prove their suitability.

Recommendation

As a result of this article review, electrochromic smart windows seem to be the most suitable and efficient smart windows for office buildings in Sulaymaniyah. Therefore, I recommend that a plan should be built and conducted to raise money and awareness in Sulaymaniyah to test electrochromic smart windows in office buildings in Sulaymaniyah in order to build better environmentally friendly office buildings

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