THE USAGE OF SMART GLASS TECHNOLOGY IN AIRPORTS TO REDUCE THE CARBON FOOTPRINT OF AVIATION FACILITIES

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Abstract: This study aims to increase awareness of a new solution for reducing the carbon footprint of airports. The use of Smart Glass technology in airports and other architectural design choices across the world mitigates the use of fossil fuels to help combat the transfer of heat and cold in buildings while bringing in a natural source of lighting in the infrastructure of buildings. The instrumental role Smart Glass technology can play in reducing energy poverty worldwide will make a massive difference in sustainability measures. In some way or form, every human in the world resides inside buildings that continue to use fossil fuels to provide comfort for people; with Smart Glass technology, we can be the new tomorrow of sustainability.

Key Words: *Architectural design, fossil fuels, sustainability, carbon footprint.*

1. INTRODUCTION

The study aims to ensure the future development of the aviation industry to pursue a more environmentally friendly and sustainable path of expansion. Implementing Smart Glass technologies inside airports and other structures will bolster the efforts of companies that are constantly in search of ways to cut down on the cost of operations. In addition to providing a sustainable environment, Smart Glass technology will also offer proper sunlight into terminals and other congregating areas inside airports.

In the world we live in today, we often find ourselves discussing the importance of energy and how to preserve it and improve the lifestyle of workers and travelers in airports. Many companies look forward to discovering renewable energy sources to reduce their carbon footprint, reduce their costs, and improve the environment. It is also imperative to have the employees and travelers feel welcomed and in an environment that is open to sunlight to make individuals feel at ease. Whether this concerns airports, many buildings currently have electrical lighting fixtures rather than built-in skylights or windows. Not receiving proper sunlight can negatively impact the health and productivity of workers and the positive feelings of passengers.

Over the past few years, we have begun implementing new ways to reduce energy usage by turning over to wind power, solar power, and even hydropower. The main issues we face with all three of these alternate sustainable energy obtaining methods are usually their costs. Wind, solar, and hydropower are costly to build, especially with all the planning and studies to place them around airports. Wind power does not work due to having obstacle clearance issues since planes have to land at runways. Solar energy has the issue of firstly conducting solar glare analysis. The glare analysis can throw away this idea if it causes problems in pilots' visions or aircraft control towers. However, another underlying issue is the availability of land to build solar panels. Airports already struggle with owning land around them and must deal with many problems. Lastly, hydropower requires a water source near an airport, and not

everywhere has access to the water point. Not only this but hydropower has been known to cause specific issues with the environment, such as hurting the population and habitats of certain animals, which is why it is not preferred. The alternative way I believe that airports can use sunlight to reduce costs in an environmentally friendly way is to use Smart Glass windows.

A study was done in the UK by Gupta, Howard, and Zahiri that shows the negative impacts in a work environment, such as health and sickness, can cause employers in the UK around £9 billion a year (2020). Improving workflow and passenger satisfaction in an airport can reduce the cost of employee issues, which can be introduced with the use of Smart Glass windows. It can also increase passengers' spending habits due to being in a better mood and feeling relaxed in the fresh atmosphere provided by Smart Glass implementations. The passengers will be under less stress as they navigate an airport that is better climate-controlled and naturally lighted. Allowing airports and other buildings to use Smart Glass windows or smart film could allow sunlight to enter without increasing or reducing the temperature inside these buildings. The presence of natural light will benefit workers and travelers and the entire ecosystem of the structure and surroundings. The technology will also help businesses by allowing them to save on operation costs. Spending will be cut down upon electrical aspects in structures, allowing for the mitigation of the business's carbon footprint. The main area that would positively affect the facility would be reducing the use of the HVAC system in the buildings.

2. BACKGROUND OF ENERGY POVERTY AND GOALS TO ADDRESS THESE ISSUES

The need to improve upon energy costs has been happening since the early 1970s. As stated by Rissman and Kennan in their study on the government's role in energy technology, "The OPEC oil embargo of 1973 was the initial impetus for the United States government to develop energy efficiency technologies" (2013, p. 2). The increase in oil prices has also driven the energy sector's expenses due to using non-renewable energy sources such as coal to produce electricity and oil to bring heat into buildings. The need to improve upon costs leads us to seek and find Low-e glass to find a way to cut down prices. In our present-day, people are now concerned about climate change and global warming. The push for the reduction of carbon footprint is greater than ever. Even airports have significant sustainability grants if they comply with a certain number of regulations to provide cleaner energy in their facilities. Thanks to the Federal Aviation Administration, programs such as Voluntary Airport Low Emissions Program (VALE) and Airport Improvement Program (AIP) always push airports to continue their improvements towards airport sustainability programs, AIP mainly provides airports that comply with sustainability management plans, grants, and funds to reduce airports' environmental impacts while VALE make sure airports comply with state issued air quality initiatives. (FAA, 2021).

The threats imposed by carbon emissions overall have increased the effects of global warming. The earth has been dealing with climate change problems for a few years now, and we are beginning to see those effects. Areas have experienced extreme heat, leading many to use their HVAC systems more frequently. In a research journal by Randazzo, Cian, and Mistry (2020), it is brought to attention that residents and businesses have a broader demand for electricity usage throughout the world. The rise in electricity usage is mainly due to the adaptation of air conditioning units.

Due to extreme heat, the problems of thermally cooling individuals' homes have risen. If companies want to run these cooling mechanisms, the user needs to run off electricity, which can be relatively expensive to obtain. In an attempt to cool homes and businesses, these applications' high prices and negative impacts can lead to energy poverty. Energy poverty described by Faiella and Lavecchia (2019) is "a complex and multidimensional problem, lying at the intersection between household income, energy costs and the energy efficiency of the housing stock" (p. 2). This means it can happen to anybody or business under the right conditions of poor energy management.

The global shift in climate change also brings colder weather to many countries and, as recently seen in the world, snow to places like Texas, which usually never see snow. Many places experience these extremely low temperatures, so they tend to crank up their thermostats. The use of heat in buildings

usually drives from furnaces and boilers to provide heat to the people. The ability to run these furnaces and boilers tends to increase our global warming as it is not the best choice for the environment. Lechner's book states, "Buildings use about 48 percent of all the energy consumed, with 40 percent for their operation and 8 percent for their construction. This energy is mostly derived from fossil sources that produce the carbon dioxide that is the main cause of global warming" (2014, p. 2). The importance here is to focus on sources that will eliminate the carbon footprint left behind by businesses and create a cost-effective way to run renewable energy sources.

This can work by introducing Smart Glass windows to the equation. Businesses can install skylights or windows with this technology to allow light into the building but limit the UV rays that cause heating. Implementing Smart Glass windows or smart films would be the best way to improve airport operations' cost reduction. Implementing Smart Glass windows will help the airport reduce its carbon footprint. The implementation of windows will allow the airport to allow sunlight into terminals, food courts, and shopping areas. Implementing the windows will also provide better control of interior temperatures, reducing the cost of HVAC. If air conditioning and heating are taken out of the airport's expenses, it will save money and allocate the budget to improve other weak areas.

2.1. The Goals of Smart Glass

The application of Smart Glass will reduce the energy usage of airports. Due to the glass's adjustability, the airport will use less heating and A/C components in their terminals. The glass will allow more UV rays inside through adjustments to keep heat inside while blocking out cold air with its double insulation system in lower temperature times of the year. In months when we see the high temperatures, the glass will block UV rays but allow natural light to come through. The airport will benefit from natural light without sacrificing to heat the facility only to waste energy cooling it back down.

Due to the glass' innate nature, it is not required to be powered by fossil fuels, like the HVAC system. It will also not be emitting greenhouse gasses to prevent further holes in the ozone layer. The glass will not use natural gas or furnaces to heat the area. Since there is no usage of fossil fuels, the glass will improve the airport's sustainability factors. As many of us are aviation experts, we are aware of AIP by the FAA. With Smart Glass technology installation, the airport will comply with AIP initiatives to create a sustainable airport. Doing so will allow the airport to receive grants and funding to allocate its annual budget to support other features the airport might lack. The money made here could improve SMS and other safety initiatives in the airport to improve the community's work and travel environment.

When Smart Glass technology is used at the airport, it will drastically improve its carbon footprint. It will take some time to kick in and show the reduction. However, more glass being installed in the airport will reduce the airport's usage of fossil fuels and other environmentally harmful energy sources. Even if the airport still uses some fossil fuels, a slight reduction will be beneficial. The initiative to reduce carbon footprint does not happen overnight but can be slowly adaptive to be more affordable and effective for the airport.

2.2. Flexibility of Options for Smart Glass Applications

The Smart Glass technology can be seen almost as a glass sandwich. The system is more intricate then having a glass layer that can allow UV rays in and block them. Many different materials are sandwiched between two separate layers of glass. Hillmer et al. (2021) presented to us in a fashion that explains how some of the science works behind it. The glass comprises a simple plane windowpane in a double insulation glazing window. The next crucial aspect of the glass has the mounting adapter that allows separation between the windowpane and the micromirrors. Lastly, the glass has the micromirror array module, which is the main element that will help differentiate unwanted sunlight and allow sunlight when the user desires it (Hillmer et al., 2021).

The micromirrors are nanostructured mirrors that adapt to day light's presence and detect human existence on the other end to allow sunlight in or deflect it accurately (Hillmer et al., 2021). The double insulation allows noble gasses to fill the gap, allowing the micromirrors' properties to react appropriately and adjust their movements based on the sunlight's presence. The micromirrors have a slight separation

known as the isolation layer. The layer allows for the transfer of negative and positive charges that adjust the micromirrors. Above the isolation layer, the photoresist layer that is baked in allows for undesired etching underneath this layer to ensure the micromirrors have a well-stable and fabricated area to be placed upon. The photoresist layer to ensure the stability of the micromirrors is also known as the FTO layer, allowing the electrode to flow through. The fourth primary layer in the installation will be a window frame that will hold all these parts together. Lastly, the job will end once the second layer of the windowpane is installed on top of the window frame (Hillmer et al., 2021). Once completed, the window will be ready to be installed into a spot to conduct its job. It allows the windows to heat a room and provide a natural light source. The application reduces the amount of heat transfer without lowering the room's brightness to still cut back on lighting costs.

Another type of glass that is much more readily available is low-emissivity windows. This type of Smart Glass is more straightforward than having a double insulated layer, thus costing less than its counterpart. Low-e windows are still insulated glass; however, they do not have as much layering as the micromirror example. In a study conducted by Rissman and Kennan (2013), they mentioned this glass's internal structure. They say, "low-e window uses two panes of glass, with a gap between them. A microscopically thin metal or metallic oxide coating is applied to one of the two inner surfaces (those facing the cavity between the panes). In higher-performance low-e windows, the air in the cavity is often replaced with an inert gas that has lower thermal conductivity than air (such as argon or krypton)" (Rissman & Kennan 2013, p. 2). The glass here is much simpler, which translates to less spending on the investment in the company's Smart Glass window application looking into the technology.

The applications that Low-e glass conducts are not very different from their counterparts (Rissman & Kennan 2013). They both do the same job, except that Low-e glass does not detect humans' presence in a room. The main advantage that is provided by Low-e glass is that it transmits the most visible light and blocks the most infrared radiation that causes heat inside airports. However, the application here might seem negative if individuals desire to heat an airport's interior since the inside of an airport is hotter than the outside during cold days. The glass uses the same application that keeps hot weather out during the summer but reverses the process to keep the airport's warm temperature during cold weather situations. Rissman and Kennan's (2013) study describes the process of heat staying indoors during cold climates and outdoor in hot climates, "This concept is known as transmittance, which is simply the percentage of radiation that passes through a material.11 A window will typically have different transmittance values for visible light and for heat" (p. 1).

2.3. Benefits

In conjunction with heat, the heat in buildings usually drives from furnaces and boilers to provide heat to the airport. The ability to run these furnaces and boilers tends to increase our global warming as it is not the best choice for the environment. Lechner (2014) stated in his book, "Buildings use about 48 percent of all the energy consumed, with 40 percent for their operation and 8 percent for their construction. This energy is mostly derived from fossil sources that produce the carbon dioxide that is the main cause of global warming" (p. 2). The importance here is to focus on sources that will eliminate the carbon footprint left behind by businesses and create a cost-effective way to run renewable energy sources. The implementation of windows will allow the airport to allow sunlight into terminals, food courts, shopping areas, and other locations. Implementing the windows will also provide better control of interior temperatures, allowing for reducing the cost of HVAC. If air conditioning and heating are taken out of the airport's expenses, it will save money and allocate the budget to improve other weak areas. One company that provides these Smart Glass installations is View. The company, View (2021), has already installed smart windows at San Francisco International Airport and has claimed that "View Smart Windows helped the SFO Terminal 1 Project realize $900k in savings, which is driven by a 25 CFM reduction in ventilation."

The service provided will allow the airport to have the glass installed into the airport. Once that is done, the airport will control the glass and change its levels to allow a certain amount of light to enter for different scenarios. The technology can be controlled through software such as Alexa and other control

assistance to allow instant modification of the environment. This feature will enable companies to save time by not worrying about adjusting the blinds to various lighting conditions during the day. Whether to clean and get rid of dirty bacteria on blinds or for maintenance, plastic blinds can be sun-bleached and eventually break. That said, the glass will help airports save money by continuously reducing UV rays during high temperatures to prevent heating in the terminal areas. This will have the benefit of airports running less AC. With the help of the glass technology, the airports will work their way into complying with more sustainability initiatives so they can receive AIP grants for keeping their airport eco-friendly. The data gathered from the United States Environmental Protection Agency (EPA) states, "Homeowners spend an estimated $73 billion or 29 percent of their total energy-related expenditures on space heating alone, whereas commercial buildings spend more than $27 billion or 15 percent annually" (EPA, 2021, para. 2). The data here shows an astronomical amount is spent on the commercial side and homeowners' expenses that can be mitigated with Smart Glass technology. Furthermore, Smart Windows leads to 95% overall occupant delight, 15 degrees cooler temperatures, 102% higher restaurant sales, and 83% longer gate dwell time (View, 2021). The occupant delight is vital because it introduces passenger dwell time in airports. The dwell time usually equates to passengers spending money in restaurants, vending machines, bars, and other amenities offered at airports. The cooler temperatures also provide a comfortable environment, making passengers more relaxed and less stressed, which helps individuals spend more money. As stated by Wong and Chan (2013), "The use of a photovoltaic smart glass system provides significant cost savings regarding heating, cooling, lighting, and overall energy bills. Smart glass represents a technology with a great deal of potential to reduce energy demand" (p. 2). The implementation of the Smart Glass technology provides the backbone for a new sustainable environment in airports and other architectures that will help shape the world's future in a more environmentally friendly way.

3. RESULTS

This section discusses the qualitative and quantitative research results. The qualitative research questions are as follows (1) Can it be possible to reduce the carbon footprint of airports and other buildings by implementing Smart Glass windows,2) Can the use of Smart Glass windows bring in enough sunlight to affect the moods of workers and travelers in the airports, and (3) What are the emotions and feelings of workers in terminals.

The quantitative research questions are as follows (4) Can the use of Smart Glass windows bring down the cost of spending on heating and cooling of a company, (5) Can the implementation of Smart Glass windows bring airports to achieve funding from AIP. These questions allow for an understanding of how the research can benefit companies and the planet by eliminating high operations costs and reducing carbon footprint.

Some questions revolve around the mood of workers and passengers. The process here shows that individuals are the key to income in the airport. The passengers are the ones who occupy and bring in cash to buy food, drinks, tickets, and other amenities offered at airports. On the other hand, the workers provide comfort and help passengers fulfill their desires. If the workers are not happy, they will reflect their moods upon passengers, thus losing profits for airports in the long term.

3.1. Interview/Survey Questions

Here are the questions asked to airport managers and other personnel to gather data on energy usage and implementations of Smart Glass technology. The survey questions are categorized by the qualitative and quantitative questions.

Qualitative

1. When you work in the airport, do you have the urge to go out and get fresh air and sunlight? Do you believe the implementation of smart windows/skylights would help with that?
2. What is your view on sustainability in airports?

3. If I were to tell you that sunlight can improve the moods of passengers and employees in the airport, would you be interested in installing smart glass windows/skylights?
4. How could the design of airports in the future improve upon sustainability acts?

Quantitative

1. What percentage of energy that is being used in an airport is sustainable?
2. How much do you think your airport spends on heating and cooling? Does your airport implement initiatives to reduce these costs?
3. What percentage of airports in the USA practice sustainable energy solutions?

4. CONCLUSION

This study aimed to increase awareness of a new solution for reducing the carbon footprint of airports. The study methodology utilized an interview design conducted with airport managers focusing on understanding the energy usage of airports. The results suggest environmental and financial benefits of Smart Glass for the Aviation Industry. The installation of Smart Glass technology will help airports save money on energy spending and reduce their carbon footprint. It will also provide a better environment for passengers and workers in the airport by providing natural sunlight without the UV rays that make the environment hot.

Three different future research studies were identified. The first study would be to perform environmental studies of Smart Glass to identify further the advantages gained by airports that have implemented technology. The second study would be to publish case studies of existing airports utilizing Smart Glass to spread further awareness of the benefits reaped by this technology. The third study would identify the barriers airports have in implementing this technology to further understand how to address these challenges. Overall, it is important to spread awareness of the benefits of Smart Glass in airports because it provides comfort to people while reducing the use of fossil fuels.

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