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Towards Sustainable Building Operations: Integrating Automated Controls and Smart Technology

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Abstract

The world is currently facing a severe shortage of energy due to the widespread use of non-renewable energy sources in every factory production, which also contributes to the alarming concern of greenhouse effect. According to a report by the Bangladesh Power Development Board (BPDB) in 2019, the residential and commercial sectors accounted for 12.3% and 13% of the country's total electricity consumption, respectively. To address the need for transitioning to renewable energy sources, it is important to focus on reducing energy consumption in commercial buildings, where heating, ventilation, and air conditioning (HVAC) systems are major consumers. Manual operation of HVAC systems is a cause for significant energy wastage, and automated control systems can be implemented to reduce this wastage, particularly in commercial buildings. Again, we will use smart glass technology in building façade which will enhance the energy efficiency of buildings by regulating the amount of light inside the building based on natural light intensity outside. This paper recommends that policymakers, building proprietors, and architects give due consideration to the integration of smart glass technology into building design to reduce energy consumption, mitigate greenhouse gas emissions, enhance indoor comfort, and diminish energy wastage by implementing automated HVAC control systems.

Keywords: *Energy Efficiency; Smart Glass Technology; Automated HVAC Control System; Renewable Energy; Sustainability*

1 Introduction

Globally, there has been a growing focus on sustainability and the requirement for environmentally friendly procedures across different sectors. Building operations are one area that has a lot of promise for lowering environmental impact. A new era of sustainable building management is starting with the rise of automated controls and smart technology (Kant et al., 2018).

The paper emphasizes the significance of these developments in converting conventional building operations into effective, eco-friendly systems. Building managers can reduce waste, improve tenant comfort, and optimize energy use by integrating automated controls and utilizing smart technologies.
Automated controls make it possible to monitor and make changes to a variety of building systems, including HVAC, lighting, and ventilation. These controls make sensible choices using sensors, data analytics, and machine learning algorithms to make sure that energy usage is in line with actual demand. These capacities are further enhanced by the incorporation of smart technology, which enables smooth connectivity and communication between various building components (Aghemo et al., 2013). The adoption of such integrated systems can help building operators accomplish a number of important goals. Firstly, dynamic control and optimization can considerably increase energy efficiency. Without losing comfort, excessive energy use can be reduced by carefully altering HVAC settings based on occupancy patterns, weather, and other variables.

The second benefit is an improvement in the general sustainability of building operations due to the integration of automated controls and smart technology. It is possible to identify areas for improvement, track performance indicators, and implement focused strategies for lowering waste and environmental impact by actively monitoring and regulating resource utilization. Beyond energy savings, the combination of automated controls and smart technologies offers advantages. The performance and lifespan of building systems can be maximized through planned upkeep and issue detection. Additionally, it gives building occupants more authority over their surroundings, promoting engagement and well-being.

Overall, integrating automated controls and intelligent technologies has enormous potential for shifting building operations toward sustainability. This strategy enables building operators to optimize energy consumption, improve occupant comfort, and reduce environmental impact by utilizing real-time data, intelligent algorithms, and seamless connection. Using automated controls and innovative technologies represents a vital step in attaining sustainable building operations as we advance toward a more sustainable future.

2 Energy Consumption in Commercial Buildings

Energy consumption of commercial buildings contributes significantly to the world's overall energy demand. These structures include offices, shops, hotels, hospitals, and other non-residential structures. The average energy use for commercial buildings is shown in Figure 1. Heating, cooling, lighting, and ventilating interior spaces account for more than half of the energy use.

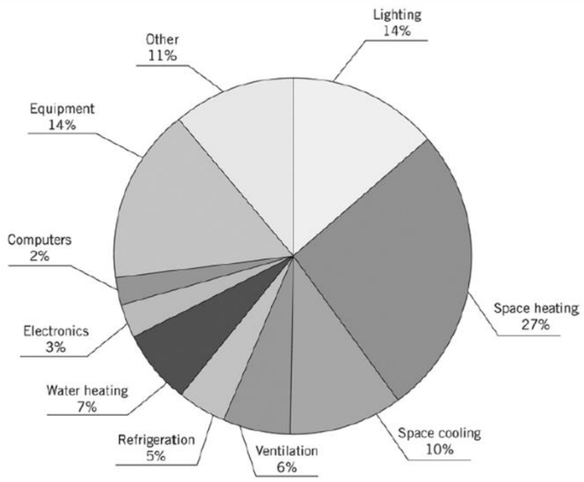

Figure 1. Energy use breakdown for commercial buildings (Adapted from DOE, 2012).

It is simple to realize why commercial buildings use such a large amount of energy. So reducing the wastage of energy in commercial buildings is a major challenge.
There are some major sources of energy used in commercial buildings:
i) Lighting
There are various reasons why commercial buildings require a significant amount of energy for lighting. In addition to being a need for all types of commercial buildings, lighting also frequently requires a significant number of bulbs, depending on the size of the structure. As commercial buildings provide services or are generally public buildings so there is light all the time (Baharudin et al., 2021).
ii) Using the more electric appliance
There is no doubt that Since computers became available all over the world, more devices than ever before are being plugged into the wall. Our office buildings are not only full of computers, but also full of monitors, printers, physical servers, and— the list goes on.
These excessive plug loads are not the only fault of office buildings. Think about a hospital that makes extensive use of medical equipment and monitoring systems. The well-being and health of patients have improved significantly thanks to these devices, but their operation consumes a lot of energy.
iii) HVAC: Heating, Ventilation & Air conditioning
In any interior space, especially one that is shared by many people, proper ventilation is essential. In fact, a lot of energy goes into creating an effective ventilation system for a structure. The ventilation system used in most commercial buildings is mechanical ventilation. These systems, which include fans and air circulation units, function by removing used indoor air and refilling it with outside air. This air exchange represents a substantial energy source since in order to maintain the proper internal temperatures, all fresh air that enters a structure must be heated or cooled (Li et al., 2013).
We require a climate-controlled environment in order for us to perform our best work. Additionally, the air conditioning systems used in commercial buildings must be strong enough to effectively change the temperature of a large area, and this is no easy feat. A sophisticated heating system is also necessary, much like cooling. Boilers,

heat pumps, and commercial gas water heaters are the most popular types of heating systems for businesses. One issue with a heating system is that the necessary temperatures will vary based on how many people are in the building at any particular moment. As the presence of humans is not the same all the time so, this makes the idea of heating a building to a certain temperature a very ineffective technique.

3 Methodology

As energy consumption rate is high in all over the world so it is necessary to reduce energy consumption and move towards sustainability. The primary objective of this paper is to minimize the consumption of energy through the integration of automated controls and smart technology as a means of achieving sustainability by analyzing existing research, and best practices. More specifically we have focused on automated lighting & HVAC controls systems and smart glass technology using in commercial buildings. This research was structured into two stages. The initial stage involves conducting a concise review of pertinent Literature to describe what is smart glass technology & automation in building and how automation system is used in HVAC & Lighting control systems. The last stage is dedicated to the investigation of the tangible effects of this Building Automation and Control System (BACS) on energy utilization within commercial buildings.

4 Automated Lighting Controls for Energy Efficiency

In the era of urbanization commercial building is increasing rapidly and energy demand is very high. So, it is more important to focus on minimizing energy use. Compared to residential buildings — Not everyone has the practice of turning off the lights when leaving a public area, the way he does when leaving a room in his home. So, automation in lighting systems in commercial buildings can reduce energy waste. As an example, we know there remains task lighting in office cubicles for employees. When he takes a break or holiday for personal need the task light of his cubicle remains on as it is controlled by the central lighting system. If a sensor can be placed, in the presence of a human the task light will be turned on and, in the absence, it will be turned off. It can save energy from being wasted. Figure 2 is a circuit diagram of automated lighting control systems through sensors.

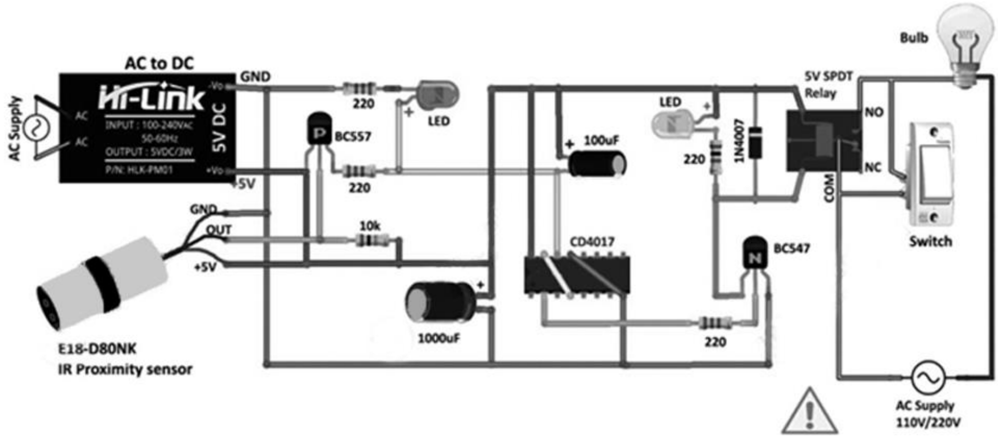

Figure 2. Automated light system circuit using 4017 & E18-D80 sensor

5 Smart Glass Technology for Building Façades

The term "smart glass technology" describes a kind of glass that may change its transparency, opacity, or light transmission properties in response to environmental stimuli or user control. UV radiation entrance may be stopped by these smart glasses up to 99% (Srivastava, 2018).

Smart glass that changes its transparency and light transmission capabilities in reaction to temperature changes is known as thermochromic smart glasses, these glasses contain special materials that undergo reversible changes in their optical properties based on temperature fluctuations. A thin coating or layer of thermochromic material, often a combination of inorganic and organic compounds, is applied to the smart glass. This material has the property of changing color or transparency when exposed to specific temperature ranges. In cool environments or lower temperatures, the thermochromic material is in such a state where light transmission is high. The glass seems translucent and permits a significant amount of natural light to pass through in this state. When the temperature rises, the thermochromic material undergoes a phase transition, which changes its molecular structure. In this amorphous state, the material absorbs more light, resulting in reduced transparency and increased opacity of the glass (Wu et al., 2023).

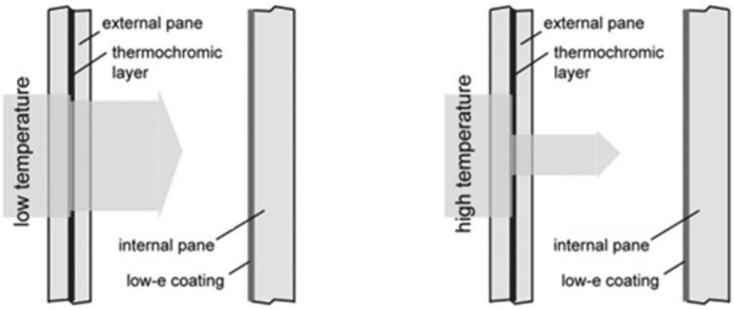

Figure 3. Double-glazed smart window with low-e coating and thermochromic layer.

Figure 3 describes how smart glass window works. Based on the temperature readings, the control system triggers the necessary electrical or thermal stimuli to regulate the smart glass. To achieve the required transparency, the thermochromic material may be heated or cooled using an electric current or a heating source. These glasses offer several benefits, including the ability to control solar heat gain, glare reduction, and privacy maintenance. Overall smart glass technology demonstrates a fascinating application, offering the potential for energy savings and enhanced occupant comfort in various architectural and automotive applications.

6 Automated HVAC Control System

As we know that most commercial buildings have central HVAC systems in recent days. This system has been controlled manually. So, it is not possible to control it all the time with respect to the human-presence ratio. If this system can be controlled automatically like when the public gathering will increase it will increase ventilation and lower air-conditioning temperature and when the public gathering will be less it will lower its ventilation and higher air-conditioning temperature at a comfortable level. Thus, we can save our energy and use energy in an efficient way. While preserving or even enhancing occupant comfort, smart HVAC systems having the ability to significantly reduce energy usage. Within the smart building software, engineers create algorithms that make the most use of database data to monitor and manage HVAC systems. These innovative controls may restrict HVAC use in vacant building areas, find and fix problems, and cut reduce HVAC use when energy demand is at its peak (King and Perry, 2017). Figure 4 is the AC automation basic circuit block diagram in which, RTD gives data to temperature controller to make value of temperature. There is a limit for temperature controller, if limit is crossed then it will give signal to PLC. Then PLC will give signal to MC for starting, then MC connection will be fulfilled and AC will turn on.

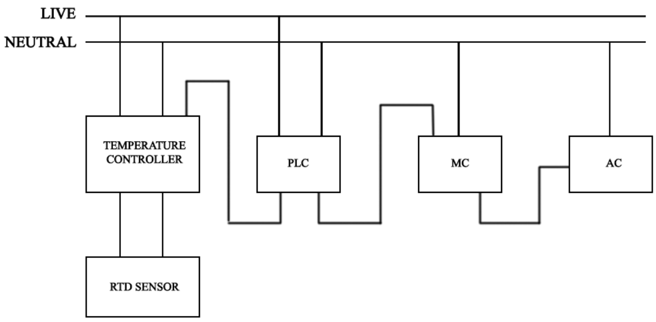

Figure 4. Automated AC control system circuit block diagram.

7 Energy Efficiency of Smart glass Technology & Automated Control Systems

40% of energy consumption and 36% of total greenhouse gas (CO2) emissions are generated by buildings (Hillmer et al., 2021). Energy efficient smart glazing glasses can reduce energy consumption by controlling natural light and temperature. In winter, this glazing glass can provide free heat from solar radiation and in summer it can prevent overheating. It can also provide natural sunlight and reduce CO_2 emissions. Switchable smart glass stands out for its remarkable capability to decrease energy expenses by up to 40% when in opaque privacy mode. Its installation not only benefits the environment but also results in substantial savings on heating, lighting, and HVAC costs. An illustrative example of these savings is the Empire State Building, which integrated switchable smart glass during a significant 2012 renovation, leading to a remarkable $2.4 million reduction in energy bills within a year (Maxim, 2018). As we know that, commercial buildings are the great consumers of energy so we should also use automated lighting control system in that. Table 1 demonstrates that the energy savings by automated lighting systems in commercial sectors.

Table 1. Commercial building subsector energy savings from smart building technologies (King and Perry, 2017)

Building type	Floor area (sq. ft.)	Automated Lighting control Systems	Average energy consumption (kWh/year)	Percent savings	Average savings (kWh/year)
Education	100,000	Occupancy sensors Web-based lighting control management system	190,000	11%	20,900
Office	50,000	Remote Lighting controls	850,000	23%	200,000

HVAC (heating, ventilation, and air conditioning) systems use approximately fifty percent of the energy consumed by the building itself (Ma et al., 2019). Through automation system this consumption rate can be reduced. HVAC automation and controls systems has led to energy savings and a shorter payback period for a variety of commercial buildings, As illustrated in Table 2.

Table 2. Energy savings in buildings by automated HVAC system (King and Perry, 2017)

Building name	Smart Building Technology	Energy Saving	Payback period	Annual energy Financial savings
Citigroup Center Chicago	Monitoring-Based Commissioning and Evaluation of HVAC system	2 million kWh/year	------	$112,000
Microsoft Headquarters in Redmond, Washington	Building Automated System, sensors, HVAC equipment	10% energy Saving from its Smart building Initiative	1.5 to 2 years	$0.25 million each year
Tryon in Charlotte office, North Carolina	HVAC controls	120,000 kWh	------	$9,000 per year

8 Conclusion

The integration of automated HVAC and light control systems in sustainable building operations is a significant advancement in energy efficiency, cost savings and environmental sustainability. These systems utilize advanced sensors, data analytics to monitor and adjust temperature, humidity and air quality in real-time. They minimize energy waste, reduce greenhouse gas emissions, and contribute to a greener, more sustainable built environment. Automated light control systems use smart sensors to reduce energy consumption and extending fixture lifespan. Although initial challenges may include installation costs and compatibility, the long-term benefits outweigh these obstacles, with energy savings, reduced maintenance costs, and improved occupant satisfaction justifying the initial investment. As technology advances, further innovations in automation and smart systems will contribute to creating a more sustainable and eco-friendlier built environment.

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