An-Najah National University
Faculty of Graduate Studies

THE EFFECTS OF USING SMART BUILDING TECHNOLOGIES ON REDUCING ENERGY CONSUMPTION IN PALESTINE

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This Thesis was defended successfully on 14/10/2024 and approved by:

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Dedication

‘’Dedicated to the memory of Palestinian martyrs’’

I literally dedicate this work

Acknowledgements

Praise is to Allah who gave me the ability and patience to complete this success. Peace and blessings be upon His Prophet and his truthful companions.

I would like to thank Dr. Mutasim Babaa'; my supervisor, for his valuable suggestions, assistance, encouragement, and for his great and continuous effort in helping me at all stages of this study.

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Declaration

I, the undersigned, declare that I submitted the thesis entitled:

THE EFFECTS OF USING SMART BUILDING TECHNOLOGIES ON REDUCING ENERGY CONSUMPTION IN PALESTINE

I declare that the work provided in this thesis, unless otherwise referenced, is the researcher’s own work, and has not been submitted elsewhere for any other degree or qualification.

Student's Name	**Mohsen Mohammad Abodiak**
Signature:	
Date:	**14/10/2024**

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THE EFFECTS OF USING SMART BUILDING TECHNOLOGIES ON REDUCING ENERGY CONSUMPTION IN PALESTINE

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Abstract

The research in this thesis focuses on the potential of various smart building technologies in increasing energy efficiency and rationalizing consumption in buildings in Palestine. Using simulation programs such as DesignBuilder and EnergyPlus, Comprehensive study of the impact of each technology on total energy consumption was conducted. The focus of this research was on lighting systems, shading systems, and heating, ventilation, and air conditioning systems. Each of these technologies was simulated and more than one procedure was performed for each technology, to reach the best technology and the best energy savings.

In lighting systems, occupancy sensors, natural light sensors, and linear control of lighting systems were used, it is found that using these technologies reduces energy consumption by 23% to 24%. In shading systems, smart inside blinds, smart films, and smart louvres were used, and the savings rate was 26%, as the results showed. In heating, ventilation, and air conditioning systems (HVAC), smart technologies such as smart economizers and heat recovery were used, it is found a savings rate of 2% to 6%. These results show the great benefit of using these technologies in reducing energy consumption, increasing energy efficiency, and achieving rationalization of consumption.

The study also clarified other technologies and methods that would contribute to achieving integrated smart buildings, including integrating smart buildings with the smart grid, which would increase the flexibility of the grid and increase its reliability. As well as integrating photovoltaic energy systems with smart buildings. Also, integrating electric vehicles with smart buildings, through which the building's energy demand can be met during peak periods by taking energy from batteries to the building. Predictive maintenance in smart buildings, and the use of predictive maintenance reduces wasted energy in the building and improves building maintenance and management methods.

This study highlights the potential that smart technologies and integrated systems can achieve with smart buildings in terms of reducing energy consumption, achieving sustainability, and occupant comfort, which enables building owners to achieve significant savings by using such systems, reducing operating costs, and greenhouse gas emissions.

This thesis provides important insights for architects, stakeholders and policy makers seeking to implement energy efficiency and rationalization solutions in Palestinian buildings. It also helps in a broader understanding of smart building applications in diverse fields and the same environmental conditions. This research encourages the adoption of modern technologies to keep pace with the global wave of energy solutions and encourages moving forward to find other solutions and move towards a more sustainable future.

Keywords: Smart buildings; energy efficiency; sensors; smart technique.

Chapter One

Introduction & Smart Techniques for Energy Efficiency in Buildings

1.1 Introduction

Buildings record for 30-40% of all energy consumption and carbon dioxide emissions in most countries [1]. In the annual report of the Palestinian Central Bureau of Statistics, the average annual electrical energy consumption in buildings was presented as 38.4% of total energy, while buildings consumption in 2020 accounted for 43.2% of total energy [2] (As shown in Figure 1). The importance of energy consumption can be explained by the continuous boost in demand, which is constantly increasing according to Palestinian statistics and negatively affects the supply of energy sources. Therefore, as a result of the high energy consumption today, a major problem has emerged due to the lack of energy availability, the problem of Palestine in importing energy due to political obstacles, and the exorbitant energy bill that makes people turn to smart building technologies, such as lighting, air conditioning systems, window shading, and others.

To ensure environmental sustainability and discourse the increasing cost of energy in Palestine, the interest of stakeholders is to reduce energy consumption in existing and new buildings, and of interest to owners, building developers, users, operators and tenants. therefore, there is an urgent need to use smart building technologies, therefore, it can be said that the smart building consists of communication technologies that enable the different systems, sensors and functions in the building to interact and communicate with each other, as well as management and control, and automate them in a remote way [3].

The impact of energy saving is positive in more than one area, including the economic and environmental areas, as it improves people's well-being and quality of life, reduces demand, lowers utility fees, and increases the resale value of the building. In parallel, this reduces pressure on the city's infrastructure and expands capital spending on strengthening other areas rather than increasing the capacity of the grid.

The potential benefits of smart buildings are vast and include not only remote control, but also the comfort of residents, energy savings, and health and well-being. Smart homes learn from the behavior of residents and try to maximize their comfort, and in terms of energy savings they significantly reduce it, and the comfort of residents is also the most important priority. This is done by providing the appropriate temperature and air conditioning, light intensity, etc.

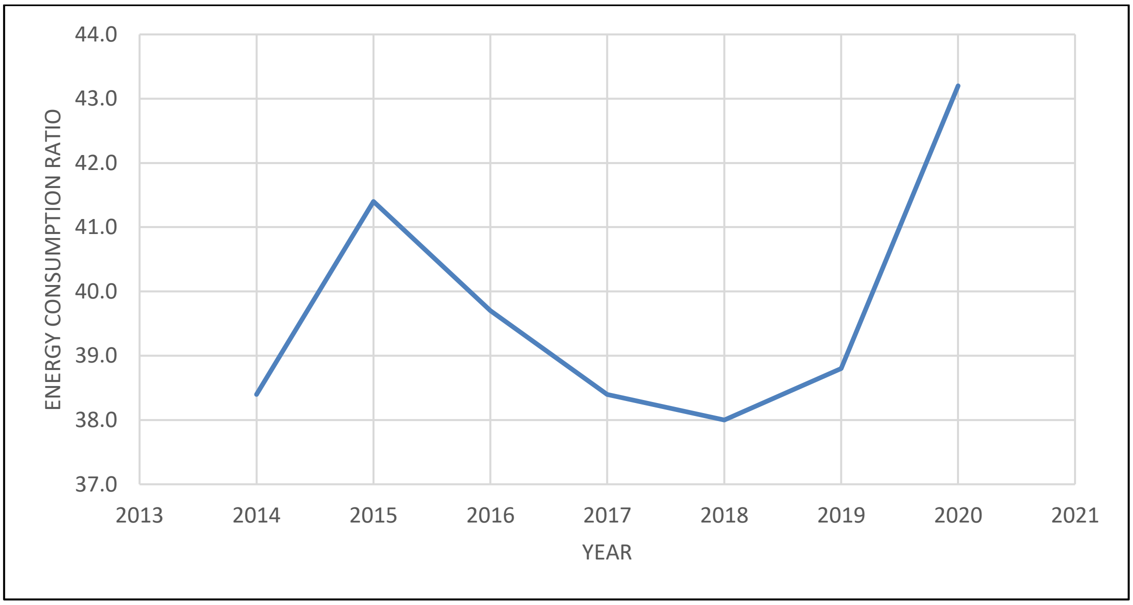
The main objective of this work is to study the effect of using smart technologies in buildings, simulate their impact on energy consumption in the building, compare different technologies in reducing consumption, and the feasibility of using these technologies in a specific building in Palestine.

Using a simulation software called "DesignBuilder" which is based on the "Energy Plus" (EP) simulation engine. It analyzes and simulates energy consumption profiles of existing systems.

Figure 1 shows the annual energy consumption ratio in Palestine and the annual increase in consumption.

Figure 1

Energy performance indicators for buildings in Palestine



1.2 Energy consumption in buildings

Energy consumption in buildings is one of the main causes of global energy consumption and global warming due to greenhouse gas emissions. Therefore, reducing energy consumption in buildings is essential to improve energy efficiency and mitigate the effects of climate change.

Energy consumed in buildings takes many forms, including hot water, electricity, cooling, and heating. Of these, electricity consumption is the most important, accounting for about 60% of total energy consumption in buildings. Lighting, heating, air conditioning, and other loads such as electronic devices are major sources of electricity consumption in buildings The heating, ventilation, and air conditioning (HVAC) system is a major contributor to electricity consumption, often accounting for a massive portion of a building’s total energy consumption.

There are many factors that affect the consumption of the HVAC system, including the geographical location of the building and the existing climate changes, and the older the system, the more energy it consumes and the less efficient it is.

Lighting is one of the most energy-consuming systems inside a building and has a significant impact on the electricity bill, especially if the lighting used is old lighting such as incandescent lamps, as it increases consumption significantly, unlike LED lighting, which is currently more widespread because it is more efficient. In both technologies, the number of hours of use, the number of lights present, and the methods of controlling them play a significant role in their impact on energy consumption.

In addition, in all energy consumers in buildings, the behavior of building users affects electricity consumption, such as turning off unused electronic devices and turning off unnecessary lights, all of which clearly affect consumption. Another important thing in the building is the design of the building because if skylights are used in the design that provide natural lighting, this will reduce consumption.

All of this leads us to the need to spread awareness and education programs that help change people's behaviors to save energy inside buildings and have a positive impact and provide practical advice that people may not have paid attention to, thus positively influencing their daily decisions.

1.3 Energy consumption in buildings in Palestine

Due to the political situation in Palestine, energy consumption is different from other countries due to the lack of industrial areas, the density of residential areas, and the presence of camps that constitute a high population density. According to the report of the Palestinian Energy Authority, the residential sector is the largest energy consuming sector in Palestine, representing approximately 55% of total energy consumption, while the industrial sector represents 35%, and the commercial sector 10%.

In terms of the previously specified energy sources, most of the energy consumed in buildings in Palestine comes in the form of electricity, then natural gas and then diesel fuel. The use of renewable energy sources, such as solar and wind energy, is limited in Palestine but is growing, especially in the residential sector.

In Palestine, efforts are being made to reduce energy consumption in buildings and increase the use of renewable energy sources. For example, the Energy and Natural Resources Authority has implemented energy efficiency programs that aim to reduce energy consumption in buildings, and there are initiatives to promote the use of renewable energy sources, such as solar water heaters, in the residential sector.

1.4 Problem statement

Energy consumption in Palestine is exceedingly high, due to the restrictions imposed that prevent the import of electricity and petroleum materials for energy production for political reasons, and therefore all energy supplies currently come from Israel at an extremely high cost.

With the increase in energy consumption in buildings and the increase in residential and commercial facilities, energy consumption can be improved and reduced by controlling the various existing variables such as cooling, air conditioning, humidity, lighting, and shading systems.

Most buildings in Palestine are built with low energy efficiency standards, so the use of various smart systems increases the efficiency of these buildings, improves their performance, and reduces their energy consumption.

There is a lack of research that studies energy consumption in buildings in Palestine, and the smart technologies that can be applied and worked on and the possibility of benefit from them has not been studied.

Therefore, this study presents smart technologies and simulates the most important technologies that directly affect energy consumption, to raise awareness and direct stakeholders to the significant importance of applying these technologies and starting to work on them.

1.5 Research objectives

In this research, the main objectives aimed to be fulfilled are as below:

1. Studying the possibility of using modern technologies to rationalize energy and water consumption.
2. Studying the impact of using modern technologies on improving the internal environment and reducing the chances of transmission of diseases and epidemics such as COVID-19.
3. Studying the effect of using smart buildings in increasing the level of comfort and safety for building users.

1.6 The importance of the study

In all countries, including Palestine, the importance of using smart systems in new and existing buildings is increasing due to the weakness of energy resources and high prices, and to face the effects of climate change and carbon dioxide emissions, in a way that maintains the comfort of the occupants and achieves maximum rationalization of energy consumption.

Given the high consumption of buildings in Palestine, there is an urgent need to study the impact of applying smart technology on buildings to compare the positive effects of reducing energy consumption and increasing energy efficiency on buildings, and thus reaching the best possible methods that can be applied and benefited from.

1.7 Study hypothesis

Main hypothesis:

1. Energy consumption in buildings in Palestine can be reduced using smart building technologies.

Sub-hypotheses:

1. The use of smart lighting systems (such as occupancy sensors and natural light control devices) will reduce energy consumption in lighting in buildings.

2. The application of smart heating, ventilation, and air conditioning systems (such as heat recovery and smart economizers) will reduce energy consumption in buildings.
3. The integration of smart window shading technologies (such as smart curtains and smart glass) will reduce energy consumption in cooling, heating, and lighting in buildings.
4. The integration of smart buildings with smart systems (such as photovoltaic systems, smart grids, and electric vehicles) will reduce dependence on the electrical grid and improve energy efficiency.

1.8 Study context and theoretical framework

Total electricity consumption of commercial and residential buildings amounted to 5898 GWh in 2020, which is equivalent to 91% of the Palestinian national electricity consumption [4].

As electricity consumption in buildings continues to rise in general, buildings can save energy by using advanced sensors and heating, ventilation and air conditioning technologies, load connection technologies, lighting, and window shading.

The aim of the research is to find the best technologies suitable for the building to reduce energy consumption and increase energy efficiency, using the simulation program Design Builder, and thus the method of work will be listed as follows:

1. Explaining the available and possible smart technologies.
2. Explaining the technologies and how to use them.
3. Explaining the smart technologies that cannot be simulated and explaining them in detail.
4. The smart technologies that will be simulated are:

   Lighting system.

   Shading system.

   Heating, ventilation, and air conditioning system (HVAC).
5. Explaining the building that will be studied to apply smart technologies.
6. Displaying the simulation results for rationalization scenarios.

7. Evaluating each case that was simulated.
8. Comparing the simulation results for rationalization scenarios.
9. Discussing the scenarios and choosing the best and least energy-consuming.

1.9 “DesignBuilder” Software

DesignBuilder is a powerful simulation tool widely used in building energy modeling to predict energy consumption in buildings. It uses the EnergyPlus simulation engine to analyze various aspects of building performance, including heating, cooling, lighting, ventilation, and overall energy use. DesignBuilder also allows users to model the building geometry, input material properties, and incorporate real-world environmental data from the site to generate accurate energy consumption predictions. By enabling designers to test different configurations of architectural, air conditioning, and heating systems, DesignBuilder helps identify energy-saving strategies and optimize building design for energy efficiency.

DesignBuilder Applications

1. Energy Consumption Prediction: Simulates energy use for heating, cooling, lighting, and appliances, and enables testing of distinctive design options to obtain the most energy-efficient options.
2. Thermal Comfort Analysis: Evaluates the comfort levels of building occupants based on indoor thermal conditions, and helps select the best insulation, air conditioning, and heating options to maintain comfort throughout the year.
3. Renewable Energy Integration: Supports the analysis of photovoltaic and solar heating systems from renewable energy sources, allowing for the measurement of the amount of energy that can be saved.
4. Natural Lighting Simulation: Evaluates the impact of natural light on interior spaces to reduce the use of artificial lighting and improves natural lighting strategies in natural lighting and air conditioning systems. It also distributes the appropriate amount of lumens for each room according to the type of room (office, administrative or classroom), and distributes lighting units appropriately within the rooms.
5. Air Conditioning and Heating Systems Optimization: Provides more than one option in modeling air conditioning and heating systems to allow for the selection of the

best available systems, while showing the effect of different control factors on energy consumption, allowing the user to add the type of system he wants and suggest more than one technology to provide better energy.

Benefits of DesignBuilder

1. Improved Accuracy: Powered by the EnergyPlus simulation engine, known for its high-precision calculations, it features the integration of accurate climate data to improve the accuracy of forecasts.
2. Cost Savings: By giving designers the advantage of experimenting with varied materials and systems before construction, it helps in determining the best options in terms of cost and life cycle cost analysis.
3. User-friendly interface: Provides a simplified user interface with a 3D visualization of the building, making it easy for users to enter data, interpret results, and simplify complex analyses.
4. Flexible modeling options: Supports distinct types of buildings, making it adaptable to various residential, commercial, and industrial projects, and provides parametric analysis options to allow users to quickly compare distinctive design scenarios.
5. Support for innovative designs: Easily add creative methods to building design, allowing the selection of modern and innovative building envelopes, passive solar heating, natural ventilation, and others, thus helping users reach the best design for energy-efficient buildings.

1.10 Smart Building Technologies

1.10.1 HVAC System

Buildings often require large amounts of energy to air-condition, with HVAC equipment typically consuming at least 40% of a building’s total energy [5]. These systems consume even more energy in many buildings, with one-third of the system being larger than the space it serves [6]. In traditional systems, HVAC systems often consume more energy than required because, even with a control system, building operators rely on trial and error to turn on and off in response to occupant feedback, thus increasing energy consumption.

Smart heating, ventilation and air conditioning systems can reduce consumption, because they have a set of sensors that are distributed within the system and send signals to the control system to reduce energy consumption and provide comfort to occupants and turn off the system in the event of leaving the building.

There are also algorithms and databases that the system relies on to know the operating times before arriving at the building and to know the departure times or rest times during work hours, all of which facilitates control and management and easy access to faults and not wasting long time on maintenance.

The following points explain the sensors and control systems that help improve HVAC systems:

1. Using Sensors to Optimize Operations

One of the sensors used in HVAC systems is the duct static pressure sensor, shown in Figures 2 and 3. This sensor measures the amount of resistance to airflow inside the duct, so that the fans operate according to the air resistance in the duct. Here, the pressure is reduced to reduce the work of the fans and thus reduce the energy consumed. These sensors give direct readings to building managers of the amount of resistance present to take the necessary measures in the event of any malfunction [7].

Figure 2

One Pressure Multi-Sensor[11]

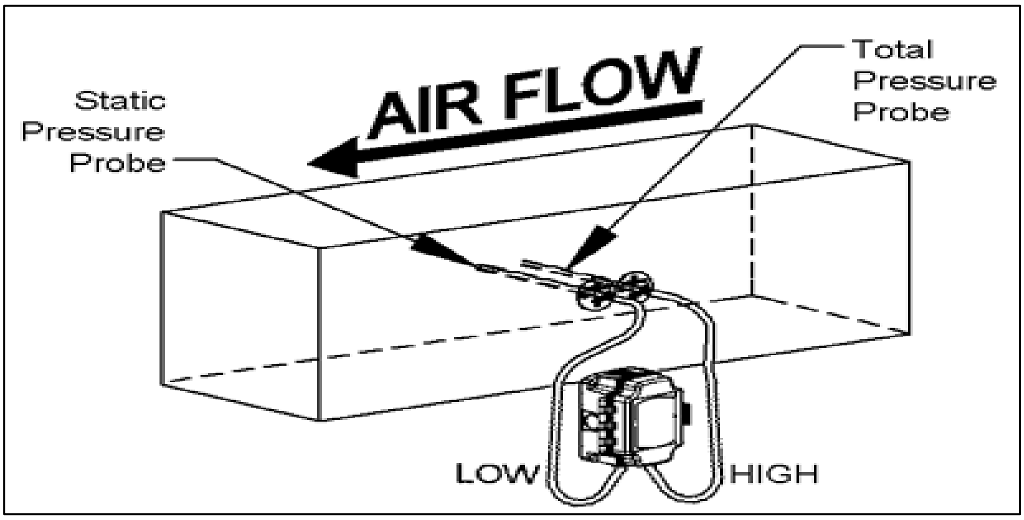


Figure 3

Duct static pressure sensor [11]

2. Controlling Multiple Zones

We are always looking for the most efficient system in smart buildings, so in multi-zone systems, the use of air conditioning can be improved by a variable air volume (VAV) system with a specific number of boxes according to the location, where the areas to be air-conditioned are divided and thus through sensors the unoccupied area can be determined and the air conditioning unit can be completely stopped and the air conditioning efficiency in the occupied area can be improved, in this way we reach the best possible efficiency.

Unlike a constant air volume (CAV) system, which has a single air handling unit, it is either effective on the entire floor or closed, and there is no flexibility to control it.

3. Fault Detection and Diagnostics

Leaks, blockages, and deterioration are routine occurrences in HVAC system equipment. If these faults go undetected for an extended time, even the most efficient equipment can waste a considerable amount of energy. Often these faults go undetected until routine maintenance is completed, or the fault's effect is noticed in the building—which could be days, weeks, or months after the fault occurs. In contrast, even the most rudimentary smart capability enables operators to immediately spot abnormalities, proactively remedy faults, and prevent system failure.

To solve these problems, automatic fault detection and diagnosis (FDD) can be used, because it contains sensors and algorithms and is therefore used primarily to compare the current operating condition or performance with the actual condition, for example, in remote control units there are air dampers that cause high energy waste, and there are two types of them, the first is open air dampers that allow outside air to enter without restrictions, and the second type is closed air dampers that do not provide sufficient ventilation. Thus, the FDD system ensures that the temperature difference between the mixed air in the remote control unit and the outside air is measured, and thus gives commands to open or close the dampers according to the temperature, and operate the remote control unit at 100% to adjust the temperature of the return air, here we can benefit from the cold outside air in the cooling process or vice versa [8].

With this FDD system, faults and malfunctions are easily detected and it is easy for building operators to assess problems remotely, avoiding wasted time waiting for maintenance workers and the time they need to find the problems. If the FDD system is connected to the supplier’s database, it can identify the problem, know the faulty part, and send a replacement request directly.

1.10.2 Lighting

Lighting controls in the past were limited to manual dimming, timers, and infrared sensors, and were not without problems due to sometimes poor design, incorrect programming or users not understanding them. Therefore, the goal of smart lighting controls is to move beyond the previous stage in terms of improving controls and finding solutions to problems.

Smart lighting is LED lights connected to the network and with advanced sensors, it can detect lighting failure and send a warning to it via the existing management system. Advanced controls can consist of occupancy sensors that work on infrared and ultrasonic waves, vacancy sensors, daylight harvesting, dimming and task control.

Daylight harvesting controls use light sensors to measure the level of indoor natural light and thus reduce the amount of artificial light according to the design requirements in that area. In one study, they found that artificial light can be reduced by 40-80% when using daylight measuring devices, in addition to ensuring the satisfaction of the building’s occupants [9].

Therefore, the technology and sensors used in lighting will be explained, images of the sensors will be displayed, and the advantages of LED lighting in lighting systems will be explained in the following points:

1. Technologies and sensors in smart lightings

A range of smart technologies and sensors can be used with lighting systems to control them, such as occupancy sensors, natural light sensors, etc. These sensors are connected to the electrical systems and networks in the building. These sensors are considered essential components of smart lighting systems.

They can detect the movement of people and natural light levels, and this information goes to the smart control center to give the necessary commands to turn the lights on, off, or dim. Thus, achieving a more comfortable and sustainable environment.

Therefore, to connect sensors and control systems, communication networks are used, which facilitates the sharing of information with each other. These networks can be wired or wireless, and all of this is linked to building automation systems, which in turn are linked to mobile devices to facilitate the work of building users or via control screens distributed within the building, which enable building managers to control, manage and maintain remotely and with ease.

The motion sensors shown in (As shown Figure 4) are among the most used sensors in lighting systems and also among the cheapest, as their operating principle depends on detecting movement in the specified area and based on it, giving commands to turn on or off. Common examples of this type are used in bathrooms, corridors, and stairs, which helps reduce wasted energy and ensure that they are operated only at times when they are required to be operated.

Figure 4

Motion and Occupancy Sensors [13]

The second type is the occupancy sensor (As shown Figure 3), this type is remarkably similar to motion sensors, but it is designed more for use in meeting rooms, school rooms and offices to control the lighting level and the dimming or turning on and off ratio.

The third type is daylight sensors (As shown Figure 5), where these sensors measure the amount of natural light and thus adjust the appropriate lighting for the room, which reduces energy consumption and provides visual comfort for people in the room. These sensors are most useful in offices and rooms with large windows or glass facades, in which case daylight is greatly utilized.

Figure 5

Daylight sensors [13]

The fourth type is photocell sensors (As shown Figure 6). The main function of these sensors is to sense day and night to be linked to the outdoor lighting and thus control the lighting by turning it on and off so that the lighting is not forgotten during the daytime, thus ensuring that the lighting is turned on at night and turned off in the morning at sunrise, thus reducing consumption and wasted energy.

Figure 6

Photocell sensors

In general, using these sensors and achieving this benefit from them as previously explained makes us aware of the importance of using these sensors, and their significant role in reducing consumption and achieving energy efficiency, and encouraging stakeholders to use them, especially with their low cost.

2. The importance and advantages of LED

In recent times, the use of LED lighting has increased and spread widely in the world due to its great benefits, advantages, and higher efficiency than its counterparts from old lighting.

When mentioning the advantages of LED lighting, there are many and we mention some of them, the high efficiency of lighting as it gives lighting in relation to the energy consumed up to 90% compared to, for example, incandescent lamps, which have a lower ratio of lighting to heat, because most of the energy consumed in incandescent lamps goes in the form of heat and the amount of lighting from the energy consumed almost reaches only 20%.

Therefore, because the energy consumed in LED lighting goes to lighting more than heat, its lifespan will be longer than its counterparts from other lighting, and therefore it is an ideal choice for use in all applications that require lighting for extended periods. Another important feature is the solidity that characterizes this lighting as it is not exposed to damage if it is shaken or moved repeatedly.

And similarly to consuming less energy, it will reduce the energy consumed in cooling because it does not emit heat in massive quantities and therefore, we do not need to operate the cooling for long periods or lower temperatures.

One of the advantages of LED lighting is the high utilization factor, because the lighting is directed in a specific direction as desired, unlike other lamps in which the lighting is distributed in all directions and thus not benefiting from all the light produced from it, and here LED lighting also excels in this important point, because it opens the way for this lighting to be shaped as desired, for example, LED strip can be used for lighting in narrow spaces or use lighting in a specific direction to focus lighting on specific items inside stores and many other advantages.

There are several degrees of LED lighting where colors can be chosen for lighting as desired and without facing problems because LED gives high flexibility to change the color of its lighting, and the possibility of dimming the light or increasing the intensity of the lighting, or movement in the lighting to suit the design of some signs.

1.10.3 Plug loads

Loads are any electrical device connected to an electrical outlet and consume electrical energy. Therefore, it can be said that electrical loads consume a large part of the electrical energy in buildings. As for the dummy load, it is the devices connected to electricity and are not in operation, but consume energy even after they are turned off, so the development of device technology or control tools reduces or stops this waste of energy.

Therefore, smart buildings deal with electrical loads in a smart and strategic way to control any device connected to the outlet. Using smart plugs is not difficult, it is just replacing the place of the regular plug, and thus communication takes place between them and the control unit. And through the control unit in managing and monitoring electrical loads by turning off the plugs remotely according to the use of the plug by the work devices in the place. It is also possible to use the scheduling of the loads on the plugs according to the experience of the building occupants or the scheduling timers. Also, building occupants can monitor the plugs and use applications on mobile phones or web applications, and program and manage load schedules.

1.10.4 Window shading

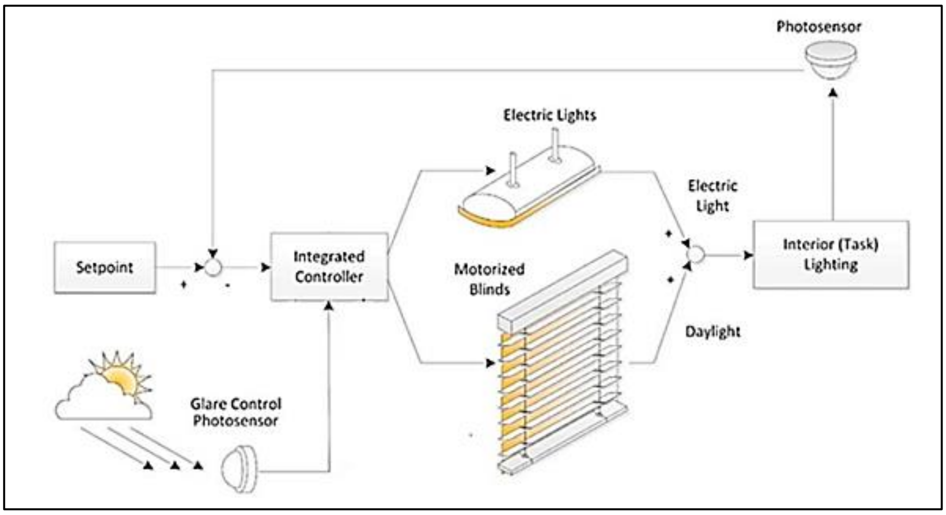
Windows account for up to a third of heating, ventilation, and air conditioning (HVAC) energy losses in commercial buildings [10]. Up to 40 percent of the cooling energy in a California building is due to heat flowing through windows, according to the California Energy Commission [11]. These studies make it important to consider windows and explore the technologies that can be applied to them.

A low-cost measure to reduce solar heat and glare is to use simple manual blinds. However, manual blinds often remain down and forgotten regardless of external changes, losing the benefit of daylight. Old window technologies are controlled by manual switches or timers, and tinted glass and films are technologies designed to absorb the spectrum of sunlight and reduce heat, thus losing the benefit of daylight.

Automatically controlled systems go a step further (As shown Figure 7), because they rely on systematic changes in external and internal conditions throughout the day without human intervention. Likewise, shading that adapts to solar radiation changes its response according to the position of the sun. Smart shades use sensors and measure internal and external temperatures, solar radiation, and its position, thus changing their position, height, or angle of inclination to obtain the best amount of light and heat in the building. All these systems can be integrated with building management systems for central control.

Figure 7

Integrated lighting and shading control systems.[15]



The use of advanced window glass and films plays a significant role in energy saving (As shown Figure 8), such as passive or low-emissivity glass technologies that are readily available. Current advanced technologies allow light to pass into the building while minimizing solar heat gain.

Figure 8

Integrated lighting and shading control systems [15]

Passive glass technologies are increasingly appearing in the smart building market, however, one of their drawbacks is that they cannot be integrated with building systems, which makes them lose many of their advantages. There are two types of them: the first is photochromic, which adjusts its color according to light and temperature, and transmits different amounts of light depending on the sunlight. The second is thermochromics', which changes according to temperature, allowing or preventing solar heat from entering the building.

Another smart type is the active smart glass or electrochromic (As shown Figure 9). These windows are operated by a low voltage charge depending on changes in sunlight and external temperature. When a voltage charge is applied to them, they darken or become dim depending on the amount of electrical charge entering them. A strip can also be attached to the glass to give the same properties if it is an old building.

Figure 9

Active smart glass [15]

1.10.5 Energy Management and Information Systems

Energy management information systems (EMIS) are a large set of hardware and software used to manage energy use in buildings. The term is similar to building management systems (BMS) [12].

The goal of energy management information systems in buildings is to bring all the control elements into one system to manage all the operations in the building, so it allows building operators to set temperature, air conditioning and heating schedules, and lighting schedules from a central location instead of manually. This system can therefore operate the cooling phase in a sequence where a smaller chiller can be used for low loads and less consumption, and a larger chiller can be used for high loads and more consumption.

The goal of energy management information systems in buildings is to bring all the control elements into one system to manage all the operations in the building, so it allows building operators to set temperature, air conditioning and heating schedules, and lighting schedules from a central location instead of manually. This system can therefore operate the cooling phase in a sequence where a smaller chiller can be used for low loads and less consumption, and a larger chiller can be used for high loads and more consumption.

Installing a robust BMS is often not cost-effective in small and medium-sized buildings, so small building owners may turn to other options, which are smart and less expensive control. For example, for the heating, ventilation and air conditioning system, programmable thermostats are used, and for lighting, occupancy sensors are used. Thus, a controller is used that will link the sensors and the thermostats to adjust the equipment, control and make schedules from a central location.

1.10.6 Human operation

All smart building technologies and analytics can fail without human intervention, so humans can choose the most useful alerts and information to receive from analytics software. Through the information displayed through smart building screens and interfaces, they can adjust and create operational schedules and strategies, and thus this information guides them to take the best measures to solve problems and reduce energy consumption, so the necessity of this information to users becomes as important as the use of smart systems in buildings.

Data Display and Prioritization

Building users are more likely to respond to data when data are presented in a meaningful way. Meaningful data is a metric that varies based on several factors, including the type of building, occupant, and owner. For instance, a basic display on the building operators.

More important than presenting information to users is presenting the information in an understandable and effortless way. There are several factors for presenting information in an understandable way, namely the type of building, the occupant, and the owner. The building operator must display key information such as energy consumption in kilowatt hours and equipment and device faults. Using panels and screens that show information on energy consumption for each part of the building is highly effective in terms of reducing consumption by occupants [13].

Therefore, modern technology gives users and building operators not just general information but what information they want to receive, for example, a building owner may want to receive large information and reports on ways to save energy, because he does not have time to analyze the large amount of information, so using algorithms it is possible to ask them to give the best three low-cost changes that can be made to reduce energy consumption in the building.

1.10.7 Distributed energy resources

Distributed energy sources are small, independent energy sources that generate electricity, for example, for a commercial building or a university campus. For example, these sources can be a diesel generator or solar energy, so the solar energy system can work with the grid or be separate from it, and it can work during peak times to reduce consumption or at specific times to cover the weakness of the electricity grid or its outage.

These sources can be used to store energy and use it during peak times, or charge batteries in the middle of the night when electricity prices are low, or a smart program can be used to monitor the switch automatically and continuously between the electrical grid and the storage system to reduce peak energy consumption.

One of the most important sources of distributed energy is solar photovoltaic energy, because it has the greatest advantage, and because the prices and initial installation costs have decreased significantly in recent years, it has become possible to install these systems either on roofs, poles or even on the ground. However, the main challenge for grid-connected photovoltaic systems is the problems they cause in the grid, which is the instability of the grid that occurs when energy is generated, and this energy is excess and the demand for electricity is low. If it is not managed properly, it will cause instability in the grid and may lead to its failure.

1.10.8 Fire Safety

In any workplace or residence, there must be fire safety systems, as the presence of these systems reduces the damage that may be caused to residents or the building, so these systems must be linked to an existing system, whether it is a regular or smart system.

One of the safety devices used is the fire alarm system, which must be distributed throughout the building to alert and warn residents or people inside the building of the need to evacuate due to the risk of fire. It is also possible to use fire extinguishing systems such as sprinklers or powder that quickly extinguish the fire, which protects against the rapid spread of the fire.

All these devices used for safety work more efficiently when integrated with smart systems to deal with them better, for example, when there is a fire, any danger, an order is given to turn off the cooling and air conditioning system and completely disconnect it from the electrical system and other existing systems according to the building, workshop or factory.

1.10.9 Security

The more advanced buildings or any other systems are, the greater the possibility of security breaches or cyber-attacks, especially in private or public company buildings. We must not overlook the importance of using security controls to make our smart system fully integrated.

One of the secure control techniques for smart buildings is access control, where specific people are identified and only allowed to access important data and information. Codes, smart cards, face, or handprints can also be used, which reduces the risk of cyber-attacks.

It is also possible to use encryption, and encrypt data transmitted between departments or sensors, alarm devices, control, and management devices, which ensures that signals and information reaching the control center are not tampered with.

With the presence of smart building technologies and the integrated building management system, all sources of monitoring and security, from surveillance cameras, security systems and all other systems, can be linked together to achieve the strongest security system that cannot be hacked and achieves all security requirements.

1.11 Literature Review

It aims to assess the current context of smart buildings and extract a successful new definition of smart buildings. This definition is intended to reflect more advanced standards, objectives and guidelines that go beyond the limits of previous terminology, as well as meet the criteria for assessing high performance buildings. We will achieve this by focusing on the key factors behind the development and simulation of buildings in Palestine [14].

The focus of this research was based on a proposal that reaches or achieves sustainability by using the features of smart buildings and applying that to public buildings in Cairo. The researcher relied in his research on reaching an architectural proposal for public buildings such that this proposal achieves the elements of sustainability by applying modern technologies specific to smart buildings that are compatible with users in Cairo.

The negative aspect of this research is that it did not rely on factual information or clear results to build on. Its advantages are that it chose smart technologies that facilitate the work of users and achieve energy efficiency and rationalization of consumption, which we will rely on in our study on buildings in Palestine [15].

The study focused on a major problem, which is the ignorance of the benefits of smart building projects due to the lack of research in this field, as well as the challenges that may be faced when trying to integrate modern technologies into them. The research used virtual models to solve the challenges of smart building projects to help building owners and designers make the best decisions throughout the life cycle of smart buildings. The disadvantage of the research lies in choosing virtual models that may not achieve the same results if real models were used. The positives are that it gives designers many scenarios and alternatives to choose the best decisions [16].

This study discusses and addresses the gap between user vision and key performance indicators in smart buildings. Therefore, the aim of this paper was to improve human health in the first place as well as their well-being in the environment inside smart buildings. Three characteristics were identified that must be achieved: health, well-being, and the design of the internal environment based on the best energy saving with the best response to the demands of the occupants. The negative of the research is the preference of human well-being over high energy consumption at a time when energy can be saved with a slight reduction in the percentage of well-being. Its advantages are considering all aspects of health that can be available in the building for human health with the best energy saving, which can be relied upon in any research related to smart buildings [17].

The researcher discussed the energy crisis and its impact on our world and pointed out the role of architects and building managers in addressing this problem by using smart and energy-efficient building designs. She also showed how smart buildings can help address the energy crisis because they help reduce the building’s operating costs. The research is particularly good, as it analyzed everything related to smart buildings and focused more on their benefits and importance in facing unexpected challenges and risks. Through the results, it was shown that the cost of constructing smart buildings is 10% higher than traditional buildings, and the operating costs of smart buildings are 35% lower than traditional buildings. We conclude from these numbers the significant role of smart buildings in solving current and global energy problems [18].

The study addressed the role of smart buildings in achieving sustainability. The study methodology was to define sustainable development and use it to evaluate the technological impact of smart buildings on economic, environmental, and social aspects. Accordingly, the positive effects of these buildings were clarified, such as reducing energy and water consumption, operating costs, increasing productivity and investment, and their role in achieving sustainability. One of the advantages of the study is that it focused on the importance of integrating intelligence and sustainability to achieve buildings with higher efficiency and lower consumption [19].

The researchers demonstrated several ways to save energy in buildings in Egypt through a set of scenarios using the "Design Builder" program to simulate the building for the study. The results indicated the high percentage of rationalization that can be obtained from using window shading in different scenarios, reaching 40%. The disadvantages of the study are that it was conducted over a period of only 6 months, and it is better to conduct the study over a full year to reach more accurate results [20].

In this study, they reviewed strategies for energy savings from the heating, ventilation, and air conditioning system in mosques in Saudi Arabia, because they are a special type of buildings that have intermittent occupancy, so that the system is operated during prayer times. They suggested strategies for dividing the load and dividing the air-conditioned areas according to specific timetables, for example, operating one area throughout the week and operating the other area only on Fridays. The results were that they reached a saving rate of 13% when dividing a mosque into two areas and 30% when dividing a mosque into 3 areas. These results give us an excellent impression of using separate air conditioning systems [21].

The researcher suggested installing infrared sensors to know if there are occupants in the rooms or not, and temperature and humidity sensors to control the cooling and humidity in the rooms. Through the occupancy sensor, it senses the presence of occupants in the room. When there is no one, the system turns off the lights according to a command received from the sensor, thus reducing energy consumption. The researcher explained in his study a control system using a computer via the web to control all aspects of the building, including lighting, ventilation, air conditioning, alarm devices, etc., and storing data and issuing reports on the best possible measures to be taken. One of the negatives of the research is that it did not present specific results, but rather explained these techniques only [22].

In this paper, a different approach was used, which is to adapt to any HVAC system, whether central or distributed. In this case, there is no need to invest in new systems or redesign the entire building. It depends on using the ACODAT program to manage the system used and choose the best and most optimal way to operate under multiple conditions to achieve the highest energy savings with the best comfort for occupants. This process is done using the building management system and control units. Before the operation process, the best case for the current situation is chosen to obtain the best operating condition. The negative aspect of the research is not considering that the old systems are not flexible in operation, but rather difficult to control to reduce energy consumption [23].

This study focused on the loads connected to the sockets, and the study concluded the use of occupancy sensors that operate on infrared rays, so these sensors send commands to the control unit when there are no occupants in the room, so that the control system in turn cuts off the electricity to the sockets, to ensure that energy is not consumed or to stop unnecessary energy drain. The negative aspect of the research is that it does not discuss the mechanism for cutting off electricity to the sockets in the event that there are devices that cannot be cut off, in contrast, a methodology can be developed to cut off electricity to specific sockets in advance, so that cutting off electricity to them does not cause problems [24].

The researcher combined the lighting system and the shading system in his study. He relied on the use of LEDs in lighting and the use of electric motors for shading windows. The study showed the benefits of using occupancy sensors in saving energy on the basis that when no one is present, the lights turn off or dim according to the occupancy. The second part of the study is to install external light sensors to open or close the motors to shade the windows according to the external light. With this process, it is possible to achieve meaningful savings in lighting energy. The disadvantages of the study are that it did not consider the external temperatures and the operation of the heating, ventilation, and air conditioning system, which may increase the consumption of this system [25].

In this research, they reached a lighting design, focusing on temperature and light intensity to ensure higher energy efficiency of up to 80% during the day, and eliminating the use of fluorescent devices to reduce carbon emissions. They also relied in their proposals on the use of LEDs and light and temperature sensors to improve control and reduce consumption. The negative aspect of the research is the lack of expansion in the systems used and the limitation to specific sensors, and the lack of clarification of the control systems used [26].

The researcher presented a model for monitoring electricity consumption at home remotely using XBee technology based on a web application, which is wirelessly connected to highly efficient sensors distributed in the home. It collects data from different areas of the house with high efficiency and uses a database to store the collected data and results in the cloud. The role of XBee here is as a coordinator in the system and collects data from sensors that depend on sensing the current and voltage of electrical devices and transmits this information to the user's computer. Through the computer, it sends alerts to places of unnecessary electricity consumption, thus reducing energy consumption. The disadvantages of the research are the lack of use of smart technologies and algorithms that support the system to control all home systems. However, it relied on a program that achieves energy efficiency through monitoring and sending alerts [27].

It was also concluded from the previous literature mentioned above that there is no research that considers the integration of smart building technologies from HVAC systems, lighting, Plug loads, window shading, automated system. While in this research all these systems are applied in one building. And studying the best possible case and the best scenarios that can be applied, and thus obtaining the best efficiency system and the maximum amount of energy saving for each of these systems, and as a result we take an integrated building in terms of the maximum possible savings and comfort for the occupants that enable the building owners to apply them to obtain a smart building.

Chapter Two

Integration of smart buildings with smart systems related to buildings

2.1 Integrating PV (photovoltaic) systems with smart buildings

Because of the electricity and energy crises in Palestine, this makes people tend to invest in renewable energy sources. There is also an urgent need to reduce the demand for energy due to the decrease in network capabilities, and due to the increase in electrical appliances and loads such as refrigeration, air conditioning, lighting, etc. All of this has made governments and people turn to investing in photovoltaics and other energy storage methods associated with photovoltaics.

Integrating PV (Photovoltaic) systems with smart buildings involves combining solar energy generation with advanced building automation and management systems. This integration optimizes the use of solar power, enhances building efficiency, and often leads to significant reductions in energy costs.

With the application of these systems, the dependence on energy from the grid becomes less, which benefits the grid and the consumer, and with the availability of smart devices that also help reduce consumption, this makes photovoltaic energy an ideal choice for use and to reduce the energy consumed.

How it works

There are a number of benefits that can be achieved by integrating photovoltaic energy with smart buildings, the most important of which is reducing consumption, followed by increasing energy efficiency, improving the network, and achieving sustainability. By taking advantage of solar energy with these advanced technologies, institutions and building owners can now create environmentally friendly buildings that are future proof. This keeps pace with the global trend towards development in renewable energy and achieving sustainable buildings.

Here are some examples and effects that could affect energy demand:

1. **Solar energy generation:**

This is done by using solar panels that exploit solar radiation to generate electrical energy, and by flexibly installing them in several places, whether on roofs, facades, or lands, so that solar radiation is exploited throughout its appearance period.

2. **Automation of smart buildings:**

Smart buildings are automated in several ways, the first of which is data monitoring, through which sensors and sub-meters are distributed to collect data that includes the amount of consumption and solar energy generation and any data coming from the rest of the sensors. Secondly, control systems that operate based on data coming from the sensors to improve building operations and analyze the incoming data, according to the variables, and these systems usually rely on algorithms and artificial intelligence to improve their operations. Finally, energy management, through which the system adjusts lighting, air conditioning systems and other loads automatically to achieve the best benefit from the generated solar energy.

3. **Integrating energy storage:**

Energy use can be improved by connecting photovoltaic energy to batteries for storage, in which case the excess energy is stored Generated during the day to be used at times when the system is not generating power, such as peak times.

There are different mechanisms for saving energy when integrating photovoltaic systems with buildings.

2.1.1 Practical examples

1. **Reducing electricity bills:**

This is confirmed by generating electricity on site from solar energy, so photovoltaic systems help compensate for the building’s demand for electricity from the grid. As a result, the building consumes less electricity supplied by the grid, resulting in lower electricity bills.

2. Optimum power consumption:

During periods of high solar generation, a smart building system can automatically prioritize the use of solar electricity over grid power. For example, it may adjust HVAC settings, top up the battery, or run energy-intensive equipment when Solar energy production is at its peak.

3. Net metering programs:

Many regions typically offer net metering or feed-in tariff programs that allow building owners with photovoltaic systems to receive credits for excess solar electricity exported to the grid. through times of high solar generation when electricity demand in the building is low, surplus solar energy is sent back to the grid, generating credits that can be applied against future electricity consumption, so net metering effectively reduces the building's net electricity consumption from the grid, resulting in additional energy cost savings.

4. Response to demand:

Smart buildings equipped with photovoltaic systems can participate in demand response programs. By taking advantage of the energy stored in batteries, which helps reduce electricity consumption from the grid by exploiting the demand cycle periods on the grid.

5. Time of Use Optimization (TOU):

This method is highly effective because it depends on different energy pricing during times. For example, prices are high during peak times and low during the day, so this can be taken advantage of in buildings equipped with photovoltaic systems, by operating during peak times to avoid unreasonable prices and thus reduce the energy consumed.

6. Long-term investment and payback:

Despite the high initial cost of this system, it is considered a long-term investment in the energy generated from it, and the returns are not current but are certain over time by reducing energy consumption. Over time, energy cost savings due to lower electricity bills and potential incentives (such as tax credits or rebates) can help offset the investment The payback period for PV systems varies based on factors such as system size, installation costs, electricity prices, available incentives, and local solar conditions.

7. **Real-time monitoring and control:**

To achieve maximum energy savings and respond to changing conditions, building management can remotely monitor the photovoltaic system, including the outputs of individual panels and the efficiency of the system, then adjust system settings and organize schedules in real time.

2.1.2 Expected impact on energy demand

1. **Reducing dependence on the grid:**

This is certain because it is done through energy generated from the sun in the same location, thus greatly reducing the use of the grid, which increases the stability of the grid and reduces consumption in general, especially during the day when production is at its highest and the demand for electricity is average.

2. **Reducing peak loads:**

As we explained with the benefits of integrating photovoltaic energy with smart buildings and the desired benefit from it by reducing loads and avoiding peak times, this procedure also greatly enhances the stability and flexibility of the energy system.

3. **Saving energy costs:**

This is through the great reliance on solar energy, here we do not need fuel, which is often expensive, and the building has become dependent on free energy coming from photovoltaic panels, and reducing its dependence on the grid, all of which leads to significant energy savings.

4. **Environmental benefits:**

This is achieved by achieving sustainability that comes from integrating smart buildings with photovoltaic systems, which reduces reliance on polluting energy sources such as fossil fuels and others, thus reducing gases and emissions from these types of fuels that certainly lead to global warming. Here we support environmentally friendly building practices.

5. Improve flexibility:

This is done by using storage systems coming from these solar systems, which constitute a reliable source of electrical energy, especially in areas where there are continuous power outages or network problems, so the building can be supplied with stored energy.

2.2 Integration smart building with smart grid

In Palestine, we face many challenges while using traditional networks, including the consumer participation rate for energy, the integration of renewable energies, and improving the reliability of the network. Electricity companies have started to introduce some smart technologies into the networks. There are also many countries that use smart grids, which provide solutions to most of the problems they face.

A smart grid can be said to be a power generation station that has a data network and combines customers and producers with high efficiency, safety, and low cost. Therefore, in smart grids, there is communication between the grid and consumers, and thus control of supply and demand is better and gives greater flexibility to the grid, which reduces electricity consumption and leads to improving existing renewable energies and managing demand that comes from the presence of information from the smart grid in real time.

Due to the presence of smart buildings supported by advanced systems and control of all building facilities, in addition to the presence of smart grids characterized by their ability to communicate and exchange information and the infrastructure prepared for work, it has become necessary to integrate smart grids and smart buildings. All of this takes us to a tremendous development in generation, distribution, and consumption.

This integration is not just a technological convergence; rather, it represents a qualitative shift in the relationship between energy producers and consumers. This leads to buildings, which were previously passive consumers of electricity, becoming active participants in the energy ecosystem. Through two-way communication, smart buildings can respond dynamically to grid signals, improve energy consumption, and contribute to grid stability.

Therefore, the existence of such a relationship between them makes many problems and challenges solvable, such as peak demand, renewable energy sources, and network reliability. Therefore, this integration can enhance energy efficiency through different mechanisms and methods, including:

2.2.1 Demand Response Programs

Demand response programs are a highly effective way to motivate consumers to reduce their consumption, in addition to reducing peak demand, which gives the consumer a good opportunity to play an effective role in improving energy networks by responding to price changes or whatever the method is. Here, demand response programs give signals to subscribers that can be relied upon in making their decisions, so the building manager or user programs the building's central automation system to stop operating some loads in the event that the conditions entered are met according to the desire of the building occupants or according to the type of loads that can be stopped.

Demand response programs are divided into three sections, which are as follows:

Incentive-based: This is an agreement between the customer and the energy company, whereby the customer reduces demand during peak times. The customer is given incentives for responding by reducing loads during the specified times, and these times may be fixed or variable depending on the type of agreement. It is possible for the agreement to be on specific loads that can be stopped for the customer. From here, the customer can benefit from reducing his consumption and the bills due to him, and from the incentives he will receive from the company.

Price-based: In this method, the price or tariff varies according to the times or seasonal periods, as the customer has nothing to do with choosing the times, but pays a higher price during peak times, and a lower price during times when demand is low. Here, the customer is placed between two options: either consumption during peak times and paying a larger amount or saving on consumption to avoid the high price. Using modern smart building systems, the customer can use price monitoring programs and choose the appropriate decision based on them. These smart systems also use renewable energy sources, if available on the site, and give them priority for operation during peak times.

Demand reduction offers: This case targets large consumers and enables them to submit requests to reduce demand. The capacity and price required to reduce demand are determined.

2.2.2 Home Energy Management System (HEMS)

It is a device that provides communication between the building loads and the electricity company to reduce or stop demand to reduce consumption, thus providing intelligent distribution between them and achieving the basic function of this system in managing home energy. This facilitates the work of energy companies in displaying energy prices to customers, directing them to reduce demand and increasing the efficiency of adding renewable systems and storage in a better way, and sending signals to the building control systems to turn off the loads to avoid power outages.

2.2.3 Smart meter

They are smart meters that can analyze and monitor the consumption of each subscriber through control signals between the network and the customer. They monitor voltage, electric current and frequency as well, and manage demand according to the tariffs coming from the company, thus achieving gains for users and energy companies, whether economic or environmental. From the network side, this helps monitor all lines to identify leakage or theft locations and monitor transformer oil temperatures, and from the customer side, it gives them reports on their consumption and billing fees, and from the company side, it gives tariffs to implement demand response programs.

2.2.4 Smart appliances

The presence of smart home devices helps in the operation of all the aforementioned systems and also increases their efficiency, because they can receive or send signals to the control unit located on site, for example, control units in energy management systems in the home, the presence of these devices facilitates the operation of the control units in terms of receiving signals or information, and if smart devices are not available, it is possible to use smart plugs, and these plugs turn regular devices into smart ones, for example, a smart washing machine can postpone certain cycles to times outside peak times, and it is also possible to use control via Wi-Fi to control the air conditioner more easily.

2.2.5 AI-Based Control

Nowadays, AI has become present in most fields, and it has become necessary to benefit from it. It can be used to control household loads in smart buildings, using smart algorithms and strategies, and artificial networks are examples of the work of AI that has become like human thinking and its learning method. AI algorithms are often used to predict or optimize energy during peak hours. Through this prediction, AI plays the role of humans in taking actions that will reduce consumption and avoid high price times.

2.2.6 Storage system

Storage systems were rarely used in energy management systems or in buildings that depend on renewable energy, due to the many problems of batteries and their high cost that building owners cannot afford, and also due to their short life, but now the trend towards them is growing exponentially due to the great improvement in renewable energy systems in terms of battery use, solving battery problems and maintenance, and reaching more efficient types.

2.3 Predictive maintenance in smart buildings

Building malfunctions and malfunctioning facilities can lead to significant energy waste. Therefore, to reduce this wasted energy and realize energy efficiency, building preservation and management methods must be improved.

Maintenance teams typically rely on accurate and exhaustive real time data to implement daily maintenance actions. However, carrying out these activities is labor-intensive and time-consuming. This leads to poor building maintenance and management methods.

Currently, maintenance in buildings is based on trial and error, such that maintenance is carried out after user complaints or unplanned errors.

From here we can move to the concept of predictive maintenance, which is based primarily on processing data coming from sensors by analyzing data, so current problems can be solved and unplanned errors can be avoided, which will help maintenance teams and reduce the time to reach errors.

Recently, modern technologies have been used in some societies, including machine learning and data science, including finance, the Internet, and medical applications, to help solve errors and avoid them[28]. Therefore, the field of maintenance has developed significantly, and the methods used have changed thanks to artificial intelligence and modern technologies used, and human intervention will become less in order to reduce the waste of time and effort and get rid of problems thanks to predictive maintenance.

2.3.1 Predictive maintenance techniques applied in smart buildings and how it works

1. Monitoring status:

This is done by deploying sensors in the building to monitor systems and equipment such as heating, ventilation, air conditioning, lighting, elevators, etc., and thus these sensors can measure different variables, and because the building contains smart equipment, this facilitates condition monitoring, and the use of the Internet of Things to collect and transfer information from sensors to the central system in the building, which facilitates monitoring and analysis in real time.

2. Data analytics:

The advantage of data analytics is that it predicts the times when maintenance may be needed, and this is done using algorithms that rely on machine learning in analyzing historical data and information that usually occurs before equipment failures. In addition, it is possible to use analytics platforms that work on prediction to process substantial amounts of data and suggest plans and insights, and they can also help identify potential problems and recommend the best strategies for maintenance.

3. Energy management, monitoring and remote-control systems:

When systems such as energy management systems are combined with predictive maintenance, a highly beneficial integration can be achieved, such as reducing energy consumption in high-consumption devices, in addition to identifying potential faults, and using the building automation system to monitor and control all systems remotely. This provides building operators with quick access to problems and address them without actually inspecting the equipment, reducing response times and equipment downtime.

4. Early warning system, alerts, and notifications:

Based on the analysis, the system can predict when equipment is likely to fail or give alerts indicating the possibility of a specific malfunction occurring at a specific time. So, when the system detects a potential problem, it sends alerts and notifications to buildings' managers or maintenance teams. These alerts can include details about the specific problem, recommended actions, and an estimated period for intervention.

5. Integrating Artificial Intelligence (AI):

This involves integrating previous technologies, including sensors, machine learning algorithms, monitoring, and control systems, with artificial intelligence to integrate these technologies together, allowing proactive planning, facilitating computing, and efficiently storing and processing data, ensuring highly efficient predictive maintenance.

2.3.2 Practical examples

Predictive maintenance in smart buildings leverages data analytics and machine learning to proactively manage building systems. By identifying potential problems and addressing them before they escalate, energy efficiency, consumption reduction and building performance will be increased.

Predictive maintenance can monitor building systems such as heating, ventilation and air conditioning systems, elevator systems and lighting systems, which may detect any malfunction in the system sensors or record and analyze the data issued by the sensors, and provide early alerts so that maintenance technicians can address the problem before the system stops, as well as in elevator systems in detecting problems such as overloading the elevator motor or friction that may lead to problems that harm passengers, or detecting high draw in the lighting system in a specific place, which may be a malfunction in a sensor or other, thus ensuring that problems do not occur that are more complex to solve.

2.3.3 Expected impact on energy demand

1. **Energy saving:**

When the loads and active systems in the building are monitored, all of this makes the loads in good condition and reduces unnecessary energy loss, for example, air conditioning systems may consume unusually high energy to reach the required temperature, and thus solving the problem helps reduce wasted energy.

2. **Reduce downtime:**

Usually, the failure of a certain system or load leads to its rapid repair or even replacement, and thus an increase in maintenance costs or equipment costs, so through predictive maintenance we can reduce unexpected malfunctions and reduce the times of interruption and stopping the operation of equipment in addition to reducing consumption.

3. **Extend equipment life:**

This is certain, as periodic maintenance, which is primarily based on prediction, can extend the life of equipment, for example, in heating, ventilation and air conditioning systems that are periodically maintained, they can operate for longer periods and with higher efficiency, and the benefits are not limited to reducing consumption only, but also reducing the impact on the environment to get rid of them.

Overall, predictive maintenance in smart buildings leverages data analytics and machine learning to proactively manage building systems. By identifying and addressing potential problems before they become worse, this improves energy efficiency, reduces operating costs, and improves building performance. This approach is consistent with the broader goal of sustainable and environmentally responsible building management practices.

2.4 Integrating electric vehicles (EVs) with smart buildings

In many buildings, batteries are usually used to provide energy in emergency situations, usually in commercial, educational or office buildings, and the costs of these batteries are remarkably high. Therefore, due to the significant increase in electric vehicles, the energy in their batteries, which are inactive for extended periods, can be used, and can be considered an important source of energy that can be used.

This brings us to the technology of vehicles to buildings as a solution, to exploit the storage capacity of batteries to operate loads in buildings, and reduces the costs of charging these vehicles and reduces energy consumption inside the building.

2.4.1 Integrating electric vehicles with smart buildings can contribute to energy savings through several interconnected mechanisms

1. Vehicle to Grid (V2G) technology:

This technology makes EVs act as a mobile energy storage source, charging electricity from the grid as well as discharging electricity to the grid when needed. Smart buildings equipped with V2G infrastructure can also leverage the energy stored in EV batteries to meet the building's energy demand during peak periods or grid disruptions, and also during times of high energy demand, EVs can then discharge the stored electricity to the building or grid, reducing the need to draw additional power from the grid and easing the pressure on the electrical infrastructure in the case of a cluster of EVs in the building. This provides a useful resource during peak times.

2. Demand response and load management:

Electric vehicles connected to smart buildings can operate on demand response programs by interacting with the grid, the building, and signals between them that motivate users to adjust their consumption and react to demand. When tariffs are high, electric vehicles can temporarily postpone charging to reduce consumption in the building, like other existing systems in coordination with the building management system, thus avoiding peak demand times and reducing electricity consumption costs.

3. Optimized charging infrastructure:

Smart buildings can deploy advanced EV charging infrastructure equipped with smart meters, sensors, and communications technologies to optimize charging operations and manage electricity demand. They can also use time-of-use (TOU) pricing and dynamic charging algorithms to schedule EV charging sessions outside of peak hours when prices are low. Electricity is less and the network capacity is sufficient, which achieves higher efficiency.

4. Renewable energy integration:

Smart buildings generating renewable energy like solar PV systems, can utilize surplus renewable energy to power electric vehicle charging stations. By synchronizing EV charging with periods of high solar generation, buildings can maximize self-consumption of renewable energy Reducing dependence on the electricity grid and reducing carbon emissions related to transportation.

5. Energy storage and grid stability:

Electric vehicle batteries can serve as distributed energy storage systems that increase grid stability and resilience by absorbing excess renewable energy or providing backup power during grid outages. Likewise, smart buildings equipped with V2G capabilities can pool the energy storage capacity of multiple electric vehicles to support grid balancing, frequency regulation, and voltage control services, thus improving network reliability and performance.

6. Data analysis and improvement:

Integrating electric vehicle charging data with building energy management systems enables better decision-making because it is based on data from vehicles and connected to the management system, thus improving the efficiency of energy resources. Thus, machine learning analytics and algorithms become able to analyze charging data from vehicles and network conditions and optimize charging schedules based on that, to achieve the highest possible efficiency.

Chapter Three

Smart lighting, shading, HVAVC Systems for energy efficiency in buildings

3.1 Smart Lighting Technologies in Smart Buildings

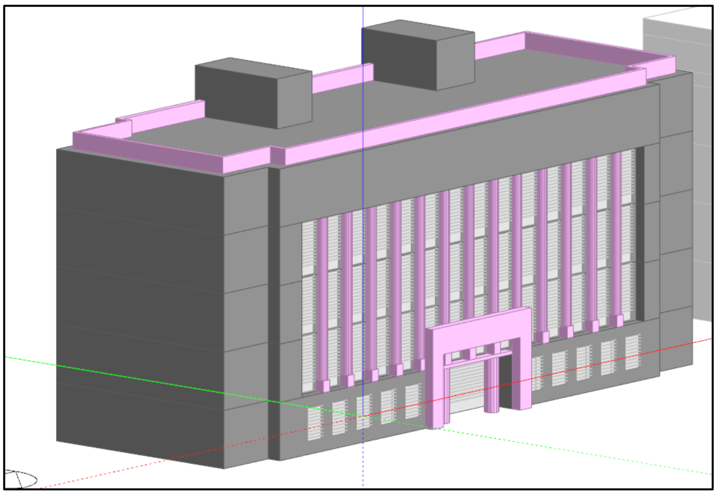
Smart lighting technologies are pivotal components in the development and improvement of smart buildings. These technologies have an essential role in achieving energy efficiency, User's comfort and building performance. This chapter reviews the diverse types of smart lighting technologies used in smart buildings, highlighting their capabilities and contributions to reducing energy consumption. The technologies used in the simulation program will be presented and each strategy will be clarified. Through the simulation, these strategies will be compared to obtain the best scenario in terms of consumption. General building and interior lighting consumption.

3.2 The building used in the simulation

This building in Ramallah is considered a case study for testing lighting, shading, and HVAC systems for the purpose of saving energy. This building has multiple rooms and multiple users per room. It has five floors in total. Each floor contains 9 rooms, 2 kitchens, 1 circulation area, and 3 rooms with a bathroom. The total number of rooms in this building is about 70, regardless of the roof section which has its own area requirements. This means that its energy needs are large.

Figure 10

3D model of the building used



DesignBuilder is a simulation program that uses different and varied control systems and gives the user wide options to control and add systems to the building, where more than one system and more than one tool can be tried to develop the building and obtain the best possible control systems. Using this program, the required building is entered, and the building's location and coordinates are entered until the simulation process is completed accurately.

3.3 Types of smart lighting technologies

1. LED lighting

LED lighting is considered one of the best that science has achieved in lighting, as it has achieved tremendous progress in the lighting industry due to its great advantages, the most important of which is providing greater lighting with less lost heat. The problem with old lighting was that it consumed a large amount of energy in heat in addition to the long work of LED lighting, and its maintenance costs are less than other lighting such as incandescent and fluorescent lighting, and it has become an ideal choice for use in smart buildings.

2. Lighting automation and control

Occupancy sensing

Occupancy sensors detect the presence of people inside space using passive infrared rays. When these sensors are connected to smart control systems, they give commands to turn the lights on or off, thus ensuring that they are operated at the times they need to be on. In the case of office buildings that suffer from fluctuating operation, wasted energy is reduced.

Daylight harvesting

The task of these systems is to measure the level of daylight in office spaces and thus control the lighting according to the levels sensed. The lighting can also be dimmed or brightened accordingly, depending on the algorithms entered the system. The goal of this is to provide comfort to occupants and reduce unnecessary energy consumption.

User-centered control

In these systems, reliance is placed on users, via distributed control screens, smartphones, or audio systems, enabling users to adjust the lighting according to their needs and facilitate control.

3. Energy monitoring and management

Energy monitoring plays an effective role in knowing where energy goes and how it is distributed because it gives building operators a comprehensive view of usage details and thus making decisions that improve energy performance and adopt the best strategies for optimal operation that achieves the best savings.

4. Integrated building management systems (BMS)

Building management systems allow effective integration between lighting systems with the rest of the building systems such as heating, ventilation and air conditioning systems and also security, and make lighting control more accurate and effective because it takes all the data received from the sensors of each system and thus achieves the best coordination between them, to reach integrated management and greater savings.

4.4 Techniques used in the simulation program

To evaluate the effectiveness of different smart lighting technologies in achieving energy savings and improving occupant comfort, a comprehensive simulation program was designed. The simulation included four distinct lighting scenarios, each using different smart lighting technologies. The purpose of this section is to introduce and describe these techniques used in simulation.

1. LED lighting

This scenario will be the reference case for comparison with other technologies, as sensors and smart systems will not be included in it, and the simulation will be for LED lighting individually.

2. LED lighting with occupancy sensor

In this scenario, LED lighting fixtures are installed in a simulated space equipped with occupancy sensors. These sensors sense people in space and control the lighting accordingly. When the space is vacant, the lights turn off automatically and activate when motion is detected, using a schedule entered to the simulation Software DesignBuilder.

3. LED lighting with linear control

In this system, the control process is as follows: when natural daylight increases, the lights begin to dim linearly from their highest wattage gradually to their lowest wattage, and they remain like this as long as daylight is high. They can be completely turned off when daylight brightness reaches its highest point, and if daylight begins to decrease, the lights begin to increase their wattage to match the light ratio.

4. LED lights with linear on/off control

Here the process is the same as in the linear control system, but the difference is that the lighting is not dimmed gradually, but rather completely turned off or on.

5. LED lights with step control

In this simulation, LED lighting fixtures are installed with step-down control. Gradual control allows smooth transitions in light levels, creating a comfortable and visually pleasing environment. It can be especially useful in places where sudden changes in lighting can be annoying.

So, the lighting can be divided into three steps, two steps, or one step. We will not see a significant effect when using one step, as it will be either on or off, while in the two steps it will be possible to turn on one or two units depending on the daylight. It will also allow us to use three higher control steps. Greater savings because it gives a higher operating range for the units.

3.5 Simulation and evaluation lighting systems

In this section, the simulation will be reviewed in two cases. In the first case, the simulation will be done using fluorescent lighting without smart systems and see the results. After that, the simulation will be done using occupancy sensor to know the percentage of saving that can be obtained. After that, in the second stage, the simulation will be done using LED lighting, as well as without and with smart systems. And note the savings.

In the evaluation, a comparison will be made between fluorescent lighting and LED lighting, the efficiency of use between these systems will be estimated, and the best system will be chosen.

3.4.1 Simulation the lighting system on the building

1. First case

In this case fluorescent lighting is used, the simulation is performed without using intelligent control systems, and the simulation result is compared with the simulation result using the occupancy sensor.
Table 1 shows the total annual energy savings when adding occupancy sensors to fluorescent lighting.

Table 1

Annual energy saving using Occupancy sensor in lighting system (fluorescent) in an office building

without smart control (kWh)	With Occupancy sensor(kWh)	Energy Saving (%)
431,286.16	273,261.32	37

Through the results, we notice the percentage of significance using smart systems on reducing consumption, as the savings rate currently reaches 34%, as this percentage is considered highly effective and achieves tangible savings. When using smart technologies with occupancy sensors, the savings rate increased to 37%, and this was the highest possible savings rate.

2. Second case

LED lighting will be used in this case and a simulation will be performed on it. First, the simulation will be performed on LED without using smart systems, then the LED simulation will be performed using smart systems, knowing the savings rate, then adding occupancy sensors to these technologies, knowing the consumption and savings rate, and thus knowing the most effective systems.

Table 2

Annual energy saving using smart control in lighting system(LED) in an office building

Type control	without smart control (kWh)	With smart control(kWh)	Energy Saving (%)	Smart control with Occupancy sensor (kWh)	Energy Saving (%)
Linear control	347,265.46	281,396	19	274,084.84	21
Linear on/off	347,265.46	274,476.79	21	268,412.33	23
Stepped control (1 step)	347,265.46	278,868.75	20	270,787	22
Stepped control (2 steps)	347,265.46	276,503.8	20	269,484.05	22
Stepped control (3 steps)	347,265.46	275,785.32	21	269,100.61	23

The results show the percentage of savings in total energy consumption, as when using linear control, for example, a savings rate of up to 19% was obtained compared to without this system. Likewise, when using other smart systems, the savings rate reached 21%, and when using occupancy sensors, the savings rate increased to 23%, due to their effective role in exploring occupancies by the users, as when there are people working with the smart systems, and when people are not present, the lighting turns off, thus saving a higher with energy.

3.4.2 Lighting Technologies Evaluation

Simulations conducted on different lighting systems, including LED and fluorescent, in parallel with different smart simulation techniques using DesignBuilder software, showed impressive results on energy consumption and potential savings. The results showed that LED lighting consumes less energy than fluorescent lighting, confirming its efficiency.

The simulation results show the great impact of using different smart control systems on different types of lighting, for example, when using old lighting such as fluorescent, a significant saving in energy consumption was observed, reaching 37% compared to the normal consumption of fluorescent, which makes us aspire to reduce consumption to a greater extent with using LED lighting with smart systems.

When simulating LED lighting without adding such control to it, we achieved high energy savings, then LED was simulated with other smart systems such as linear control, on/off system and step control, and the savings rate exceeded 20%, which alone is enough to achieve an improvement in energy efficiency, and the second stage is to apply these systems with occupancy sensors, which achieved savings of up to 23%.

These results make us aware of the significant importance of using these systems in buildings and greatly help in the effective design of buildings based on these technologies and the results extracted from them, as they increase energy efficiency, reduce consumption and achieve comfort for building occupants.

3.5 Smart Shading Techniques

Windows are considered important when designing a building, apart from their external appearance, they are now considered a passage for heat or cold to enter the building as well as sunlight. Poor design may lead to the loss of a large part of energy by having to operate the heating, ventilation, and air conditioning system for a longer time. Therefore, searching for window-related technologies is extremely useful. The presence of sensors that monitor sunlight to give an order to the windows to change the angle of inclination of the shading on them has a significant role in reducing the heat entering the building, as well as exploiting sunlight as much as possible. The use of smart shading, automatic curtains, and other types of smart systems saves the energy consumed in the building. Therefore, these systems will be studied and simulated to choose the best possible shading technology.

Types of Smart Shading Techniques:

1. Dynamic Shading Systems

The presence of automatic shading systems with smart sensors achieves an effective shading control system because they can change the window shading according to the sun angle and provide high flexibility in working to obtain natural light or avoid strong sunlight that raises the temperature of the building.

2. Photochromic or Electrochromic Glass

Electrochemical glass is considered a smart technology as it responds effectively to external conditions and the percentage of light, thus the amount of glare inside can be controlled by changing its transparency by electrical charges, preventing or reducing the glare inside the building, providing a comfortable indoor environment and higher energy efficiency.

3. External Louvers and Shading Devices

Shading devices and external slats are an important factor, especially when they are strategically installed, as these fins or slats work to disperse direct rays, which reduces heat, and allows light to enter to provide a comfortable environment inside the building, and their appropriate design may also help in showing the beauty of the building from the outside.

4. Automated Blinds and Curtains

Integrated with automation systems, motorized blinds and shades provide adjustable window coverage, in response to environmental changes or user preferences. Its automated functions allow precise control of natural light, optimizing the use of daylight and enhancing privacy. By programming them to adjust based on time of day, season, or occupancy, they contribute significantly to regulating natural light, maintaining comfort, and reducing the need for cooling.

3.6 Simulation and evaluation of shading approach

The simulation process will be done through the DesignBuilder software in three steps. Initially, the simulation will be performed without using any type of shading, so we will use this value as a reference to compare and see the savings when using smart shading types.

Three technologies will be used: interior blinds, smart films, and exterior louvers. In each technology, 17 different procedures will be simulated, such as scheduling, solar lighting, daylight, and others.

After collecting the energy consumption results, the best technology with the best procedure that achieves the best energy saving will be selected.

3.6.1 Simulation smart shading technologies

1. The first technology (Inside Blinds)

The opening and closing of the blinds is controlled by one of the following factors:

1. Always on: The shading devices are always activated.
2. Schedule: The shading process is carried out by a specific schedule. When the schedule has a value of 1, the shading is on, otherwise it is not on.
3. Solar: The shading is on if the light beam plus the diffuse solar radiation falling on the window exceeds the solar input set point.
4. Glare: The shading is on if the total daylight glare index at the first daylight sensor of the area from all external windows in the area exceeds the maximum glare index set at the daylight input of the area.
5. Outdoor air temperature: The shading is on if the outdoor air temperature exceeds the outdoor air temperature set point.
6. Indoor air temperature: On if the air temperature in the area is high.
7. Cooling: On if the cooling temperature of the area is high.
8. Day cooling and solar + night: The shading is on at night. Shading is on during the day when the solar radiation incident on the window exceeds the solar setpoint and the area cooling rate in the previous time step is non-zero.
9. Daytime and Solar Cooling: Shading is off at night. Shading is on during the day when the solar radiation incident on the window exceeds the solar setpoint and the area cooling rate in the previous time step is non-zero.
10. Low Outdoor Nighttime Air Temperature: Shading is on at night if the outdoor air temperature is below the outdoor air temperature setpoint and the schedule, if specified, allows shading. Shading is off during the day.
11. Low Indoor Nighttime Air Temperature: Shading is on at night if the area air temperature in the previous time step is below the indoor air temperature setpoint and the schedule, if specified, allows shading. Shading is off during the day.

12. Night Heating: Shading is turned on at night if the area heating rate in the previous time step is greater than zero and the schedule, if specified, allows shading. Shading is turned off during the day.
13. Low Outdoor Air Temperature at Night + Day Cooling: Shading is turned on at night if the outdoor air temperature is below the outdoor air temperature setpoint. Shading is turned on during the day if the area cooling rate in the previous time step is non-zero.
14. Night Heating + Day Cooling: Shading is turned on at night if the area heating rate in the previous time step is non-zero. Shading is turned on during the day if the area cooling rate in the previous time step is non-zero.
15. Horizontal Solar: Shading is turned on if the total (radius plus diffuse horizontal solar radiation) exceeds the solar setpoint and the schedule, if specified, allows shading.
16. Outdoor air temperature + Solar energy on the window: Shading is activated if the outdoor air temperature exceeds the outdoor air temperature set point and if the solar radiation falling on the window exceeds the solar energy set point.
17. Outdoor air temperature + Horizontal solar energy: Shading is activated if the outdoor air temperature exceeds the outdoor air temperature set point and if the horizontal solar radiation on the window exceeds the solar energy set point.

Table 3 shows the simulation results on annual energy consumption without using smart curtain technology, and the consumption results with smart curtain technology, as well as with the different control types previously explained. The following table shows the amount of savings in using smart curtain technologies and the amount of savings for each type.

Table 3

Annual energy saving using smart inside blinds in shading systems in an office building in Ramallah

Control Type	without smart techniques (kWh)	with Smart control inside blinds (kWh)	Energy Saving (%)
Always ON	355,425.65	332,929.7	7
schedule	355,425.65	334,912.2	6
Solar	355,425.65	335,904.7	6
Glare	355,425.65	280,208.9	22
Outside air temperature	355,425.65	340,510.4	5
Inside air temperature	355,425.65	341,744.2	4
Cooling	355,425.65	334,975.3	6
Day cooling and solar + night	355,425.65	336,068.2	6
Day cooling and solar	355,425.65	336,057	6
Night outside low air temperature	355,425.65	347,366	3
Night inside low air temperature	355,425.65	347,337.5	3
Night heating	355,425.65	347,265.9	3
Night outside low air temp + day cooling	355,425.65	334,973.8	6
Night heating + day cooling	355,425.65	334,860.8	6
Horizontal solar	355,425.65	334958.2	6
Outdoor air temp + Solar on window	355,425.65	341011.8	5
Outdoor air temp + Horizontal solar	355,425.65	340548.2	5

2. The second technology (Smart Films)

In the smart film technology, the same types of control in the previous table were used with the same consumption value without using smart technologies. After performing the simulation on smart films, the following results appeared in Table 4.

Table 4

Annual energy saving using smart Films in shading systems in an office building in Ramallah

Control Type	without smart techniques (kWh)	with Smart Films(kWh)	Energy Saving (%)
Always ON	355,425.65	318499.7	11
schedule	355,425.65	322307.3	10
Solar	355,425.65	325689.9	9
Glare	355,425.65	271379	24
Outside air temperature	355,425.65	333909.5	7
Inside air temperature	355,425.65	335873	6
Cooling	355,425.65	322293.7	10
Day cooling and solar + night	355,425.65	325698.1	9
Day cooling and solar	355,425.65	325696.8	9
Night outside low air temperature	355,425.65	347266.7	3
Night inside low air temperature	355,425.65	347266.3	3
Night heating	355,425.65	347265.5	3
Night outside low air temp + day cooling	355,425.65	322293.6	10
Night heating + day cooling	355,425.65	322292.8	10
Horizontal solar	355,425.65	322744.3	10
Outdoor air temp + Solar on window	355,425.65	335241.8	6
Outdoor air temp + Horizontal solar	355,425.65	333978.6	7

3. The third technology (External Louvers)

In this case, we will cancel the shading systems and use the louvers. The simulation will take place in three steps at different angles of the louver and choose the best result we get from these angles.

Table 5 shows the simulation results of using smart external louvers. Three angles of the louvers were used to show the effect on power consumption.

Table 5

Annual energy saving using smart external louvers in shading systems in an office building in Ramallah

Angle of blades	Consumption without control(kWh)	Consumption with control(kWh)	Savings (%)
90	355,425.65	269645.81	25
45	355,425.65	264692.07	26
60	355,425.65	264126.7	26.5

3.6.2 Shading Technologies Evaluation

After examining the results that we obtained from simulating the technology of smart curtains and films, we obtained 17 results from each technology we conducted from the simulation of distinct types of control, and the glare was one of the best results obtained, as the curtains had a saving rate of 22% while for smart films. 24%.

Accordingly, through these two techniques we choose the smart film technology and choose the control type glare

When performing simulations on the louvers, generally satisfactory results were obtained, such that when using different angles of the blades at angles of 90, 45, and 60 degrees, the savings were, respectively, 25, 26, and 26.5%.

Thus, using external louvers at an angle of 60 degrees achieves the best result, and this technology is chosen in addition to smart films.

3.7 Smart HVAC Systems

Smart HVAC systems use advanced technologies to achieve energy efficiency, improve comfort, and enhance control over indoor environments. Here are ways to make these systems smart, efficient, and cost-effective:

- **Controlling the heat**: Smart thermostats are an essential element in heating, ventilation, and air conditioning systems, as they can operate automatically according to previous operating conditions and learn on their own and adjust temperatures accordingly, and their advantages include the ability to control them remotely via smartphones.

- **Zone control**: This method provides high efficiency in heating, ventilation and air conditioning systems, as the building is divided into zones, and each zone has its own regulator and dampers to control the amount of air flowing, and thus each zone has a temperature that suits it and its occupants, thus improving the comfort of users and saving energy.
- **Sensors and Data Analytics**: The task of sensors in heating, ventilation and air conditioning systems is to sense external conditions such as temperature and air quality as well as internal conditions such as temperature, humidity and occupancy, and thus data analysis devices process the data received from the sensors to improve the operation of heating, ventilation and air conditioning systems to achieve the best comfort for occupants.
- **Integration with Building Management Systems (BMS):** As we mentioned previously, the integration of building systems with each other through building management systems achieves improved performance for all systems, including the heating, ventilation, and air conditioning system.
- **Energy Efficiency Features:** When using smart heating, ventilation, and air conditioning systems, they have high features such as variable speed motors that are very energy-efficient, as the motor operates in several stages and does not operate at full capacity, as well as adjusting the amount of incoming air with high efficiency.
- **Integration with smart home ecosystems**: Integration of smart heating, ventilation and air conditioning systems with smart home devices and systems, the most important of which are Amazon Alexa, Google Assistant and Apple HomeKit. These systems provide more than one form of control such as movement, voice control or on smartphones, making it easier for users to control to provide the best service.

HVAC systems are staple systems in buildings today, and they consume significant amounts of the energy consumed in buildings overall. Therefore, it is necessary to focus on these systems in terms of the smart technologies available, understand their working mechanism, and know the energy consumption of each technology, as well as the impact of each of them on all systems in the building as a whole, and to know the extent of the impact of the use of these technologies on the energy efficiency of buildings, an analysis must be conducted. These advanced technologies are simulated using DesignBuilder software. Therefore, some of these smart technologies will be explained in detail, with simulations conducted on some of their types on a modern office building that uses the traditional construction method in the city of Ramallah in Palestine.

In this research, we will study two features of Smart HVAC systems: 1- Heat recovery, and 2- Smart Economizer. The reason for selecting these features is the ability to evaluate their impact on energy consumption in any climatic zone using thermal simulation.

3.8 Heat recovery

This technology is one of the saving and necessary technologies, as the heat emitted and wasted by air conditioning devices goes to waste. To exploit this heat, it is taken to heat the air or water in the case of heating, thus reducing heating costs. In this process, algorithms and sensors are used to work together to analyze the system's data and better control and improve the system's performance.

3.8.1 Applications of smart heat recovery systems

1. Heat recovery ventilation (HRV) systems:

Heat recovery ventilation systems are designed to utilize the heat coming out of the building from the air to assist ventilation systems and transfer this air into the building, which reduces the amount of energy spent on heating the air and thus reduces costs.

2. Waste heat recovery boilers:

These type of boilers are able to capture the waste heat from industrial processes and convert it into useful energy for heating or power generation.

3. Energy recovery ventilators (ERV):

Energy recovery ventilator systems can recover sensible and latent heat from the exhaust air and transfer it to the incoming fresh air, which helps reduce energy loss.

4. Smart control heat exchangers:

Heat exchangers with intelligent control systems collect unused heat from various sources and transfer it to water or air streams for heating or cooling purposes.

3.8.2 Simulation Heat Recovery Results

The simulation results in (Table 6) indicate that using heat recovery in HVAC systems results in energy savings of 5.65% for heating and 1.83% for cooling, compared to the same HVAC systems without heat recovery.

Table 6

Annual energy saving using smart heat recover in HVAC systems in an office building in Ramallah

Mode	Consumption Without Heat Recovery (kWh)	Consumption With Heat Recovery (kWh)	Energy Saving (%)
Heating	289,475	273,068	5.65
cooling	378,237	371,314	1.83

3.9 Smart economizers

Smart economizers: (also known as smart or adaptive economizers), are advanced control systems built into HVAC systems to optimize the use of outdoor air for cooling while ensuring indoor comfort and energy efficiency. Unlike traditional savings tools, smart savings devices use real-time data and sensors to make dynamic decisions appropriate to the specific building and surrounding environment.

Key features and benefits of smart savers include:

- Real-time data integration: Smart economizers collect and analyze real-time data from various sources such as outdoor temperature, relative humidity, indoor occupancy (based on CO2 sensors), building heating/cooling load, and weather forecasts. By continuously monitoring these factors, smart savers can adjust the amount of outside air intake based on these conditions to maximize energy performance and enhance occupant comfort.
- Advanced control algorithms: Smart economizers can use control algorithms to optimize the performance of the HVAC system, considering several factors including the thermal mass of the building, the heat generated by the equipment, and the cooling capacity of the HVAC system to select the best factor for the outside air.

Adaptive Operation: Unlike traditional economizers that rely on specific set points or even schedules, smart economizers react to changing external conditions better to adjust their operation, for example, in moderate weather, the use of outside air increases and thus the use of mechanical cooling is reduced, and if the outside weather is not sufficient for cooling or heating, part of the outside weather is relied upon and part of the mechanical system is operated.

Fault Detection and Diagnostics (FDD): These smart economizers in the heating, ventilation and air conditioning system can, through their sensors and devices, detect faults quickly and diagnose them early and provide data to building operators to implement the necessary measures, to maintain the efficiency of the system.

Integration with Building Automation Systems (BAS): Smart economizers can easily integrate with the building management system, allowing central monitoring linked to the system and optimal control of it.

3.9.1 Simulation Smart Economizers Results

The simulation results in (Table 7) indicate that using smart economizers in HVAC systems results in energy savings of 4.69% for heating and 2.23% for cooling, compared to the same HVAC systems without economizers.

Table 7

Annual energy saving using smart economizers in HVAC systems in an office building in Ramallah

Mode	Consumption Without Economizers (kWh)	Consumption With Economizers (kWh)	Energy Saving (%)
Heating	273,068	260,261	4.69
Cooling	371,314	363,033	2.23

Chapter Four
Conclusion and Recommendation

4.1 Summary of Findings

This thesis has explored the critical role of smart buildings and smart techniques in enhancing energy efficiency. Through a comprehensive analysis of current technologies, case studies, and implementation strategies, we have demonstrated that smart buildings represent a significant advancement in reducing energy consumption, lowering costs, and improving overall sustainability. The integration of intelligent systems such as advanced sensors, automated controls, and data analytics has been shown to optimize energy use without compromising comfort or functionality.

Simulation results presented in chapter 4,5 and chapter 6 show that there is a good opportunity to reduce energy consumption by implementing smart technologies for buildings. Table 8 summarizes these results.

Table 8

Annual energy savings in buildings using smart technologies

Application	% saving	remarks
Occupancy sensors for lighting	23	No other sensors
Smart control for lighting	21	No other sensors
Smart Films for window shading	24	Of cooling loads
Smart control for window shading	23	Of cooling loads
HVAC systems with heat recovery Heating and cooling	5.65 , 1.83	Heating, cooling
HVAC systems with economizers Heating and cooling	4.69 , 2.23	Heating, cooling

Lighting Systems

The simulation on LED lighting achieved significant savings when using multiple smart technologies, and the benefit was great when adding occupancy sensors and daylight harvesting sensors, where we achieved a reduction in energy consumption of up to 23%. This percentage provides useful insight for managers of the building where the simulation was conducted, to study changing old systems and replacing them with these smart systems and provides a rich resource for building designers in Palestine.

Smart Shading

Smart shading systems, which adjust window shades based on the sun's position and indoor lighting needs, contribute to energy savings in both lighting and air conditioning. The integration of motorized blinds and electromechanical windows resulted in energy savings of up to 24% for cooling loads. This percentage is very feasible for making changes to this building and converting its shading to smart shading systems. Also, with these systems recently available in the Palestinian market, this study makes building owners in Palestine turn to use these systems because of their positive impact on the comfort of occupants and improving the performance of all systems in the building.

Smart HVAC Systems

Heating, ventilation, and air conditioning systems are among the most energy-consuming systems in buildings. When equipped with smart equipment such as energy savers, smart heat recovery systems and predictive maintenance, these systems can significantly reduce energy consumption. The energy savings rate when simulating these technologies reached 6%. This percentage was only when performing two procedures, which are available to us in the simulation program, as performing other techniques can reach a savings rate of at least 30%.

Other Smart Systems

At the beginning of the thesis, we mentioned the smart systems that can be applied to buildings, including building management and automation systems, smart plugs, security and protection systems, and others. These systems also contribute significantly to reducing consumption and raising energy efficiency in buildings, especially when they are integrated with each other with the rest of the smart systems that we simulated. It is natural when applying these systems to buildings to achieve huge energy savings and the best possible energy performance.

4.2 Key Contributions

1. **Technological developments**: During our study, we identified the main technologies involved in smart buildings, which are lighting technologies, smart shading systems, and HVAC systems. This study has proven the effectiveness of these systems and technologies in achieving high energy savings.

2. **Implementation strategies**: To implement these technologies and apply them to buildings, we need an accurate methodology for their application. This methodology includes monitoring and auditing the energy in the building to choose the best technologies that can be applied to it and monitoring its energy performance to provide an effective plan to improve the system. Through our presented results, these technologies can be implemented gradually to prevent disturbances to the least possible extent with the best increase in benefits.
3. **Case Studies**: Our case study presented in this thesis highlights the successful and feasible implementation of these systems in different areas in Palestine, taking into consideration the geographical location, as well as the simulation for a year with weather conditions throughout the year. The real-life examples presented confirm the savings that can be achieved and the operational improvements that come from the application of these smart technologies.

4.3 Benefits of Smart Buildings

Smart buildings provide many benefits, the most important of which are:

- **Cost Savings**: This is achieved by applying smart technologies that save energy and thus reduce bills due in the building.
- **Environmental Impact**: Reducing energy consumption reduces gas emissions that lead to global warming and achieves sustainability, as one of the conditions for reducing global warming is reducing energy consumption in general.
- **Enhanced Comfort and Productivity**: When smart systems are applied to buildings, they provide occupants with ease of dealing with the systems as well as comfort in use and thus increase their productivity.
- **Predictive Maintenance**: The best performance of predictive maintenance is when smart systems are present, reducing equipment downtime and extending the life of systems.

4.4 Challenges and Future Directions

Despite its advantages, there are challenges, which are:

- **Initial Costs**: Investing in smart buildings is expensive in terms of the systems used, and if it is an existing building, changing the existing systems is also expensive because the old systems will be replaced with modern systems, and those systems will be lost.
- **Technical Complexity:** To implement these systems, there is a need for highly experienced engineers and technicians because installing these systems is somewhat complex.
- **Data Security and Privacy**: Using smart systems linked to the Internet and with the presence of building data and all its details that follow the building's security, this exposes this data to the risk of hacking.

It is necessary for future research to focus on addressing the challenges posed and finding solutions to those challenges in terms of cost and conducting an in-depth feasibility study on each case to reach effective solutions. Governments can also take these challenges into consideration in terms of giving incentives and encouraging investors to adopt investment in smart buildings, which will benefit governments as well as stakeholders.

In conclusion, the use of smart technologies in buildings and the spread of their use within any country will advance them and open the door to their development and the creation and development of better technologies. Since this thesis provided a comprehensive view of the technologies, strategies and features related to smart buildings, adopting these technologies in Palestine is possible and effective and is considered a solution to many of the problems we face due to the restrictions on energy from the political side. Therefore, the results of this research help the government, stakeholders and even researchers in this field to navigate it and benefit from it to enhance energy efficiency.

4.5 Recommendations

The challenges in the global energy issue are increasing, and these challenges must be addressed by adopting smart building technologies more than the current time, so this thesis works to attract researchers, professionals and policy makers to cooperate and innovate in energy-efficient buildings, so the path towards smart buildings is not without difficulties and some problems, but more importantly, working with them is very rewarding and has very high rewards on all levels of energy saving, environmental impact and improving comfort, so this matter is worth the effort.

1. Integration of emerging technologies

Artificial Intelligence (AI) and Machine Learning (ML): Future research should work on integrating machine learning and artificial intelligence algorithms, as this mixture between these two technologies has great effects on the advancement of smart buildings.

5G and Advanced Communication: To increase the response and efficiency of smart building systems, the use and study of the fifth generation with advanced communications may make data collection and processing more efficient, accurate and faster in response.

2. The necessity of using unified systems

Interoperability frameworks: With the increase in smart systems and the differences in companies and existing technologies, there is a need to use unified protocols to ensure smooth communication between these systems and the various smart building systems. Also, adopting unified control panels and applications to facilitate the work of building operators and users.

3. Data analytics and privacy

Work on using advanced data analysis due to the vast amounts of data coming out of smart building devices to reduce errors and problems that may occur, and thus improve prediction and suggest the best possible plans.

Also, search for modern technologies to develop information security and privacy to preserve important building data.

4. Cost-benefit analysis and economic feasibility

Study the cost of economic feasibility of smart buildings comprehensively for all facilities and study the return on investment in them, including the entire life cycle of these technologies, and conduct studies on the impact that will come from financial incentives or facilities provided by governments on the establishment of smart buildings to encourage investors.

5. Human-centered design and occupant behavior

Conduct studies aimed at encouraging users to use buildings that contain smart technologies. These studies include the impact of smart technologies on occupant comfort and the impact on productivity, which encourages them to work within these technologies.

6. Rehabilitation of existing buildings

Work on developing existing buildings and providing effective solutions for introducing smart technologies into existing buildings and presenting studies on successful projects and highlighting the best practices and factors that contributed to their success.

List of Abbreviations

Abbreviation	Meaning
APS	Advanced power strips
ASO	Automated system optimization
AHU	Air Handling Unit
AI	Artificial intelligence
BMS	Building Management Systems
BAS	Building automation systems
CAV	Constant air volume
CO2	Carbon Dioxide
CCTV	Closed-circuit television
DR	Demand response
DDC	Direct digital control
DER	Distributed energy resources
EMIS	Energy management and information systems
EMS	Energy management systems
EIS	Energy information systems
EVs	Electric vehicles
FDD	Fault detection and diagnostics
HVAC	Heating, Ventilation, and Air Conditioning system
HEMS	Home Energy Management System
IoT	Internet of Things
KPIs	Key Performance Indicators
LED	light emitting diodes
MBCx	Monitoring-Based Commissioning
PIR	Passive infrared sensor
PV	Photovoltaic
RTU	Remote terminal unit
SBP	Smart Building Projects
TOU	Time of Use Optimization
V2B	Vehicle-to-building
VSD	Variable Speed Drive
VFD	Frequency speed drive
VAV	Variable air volume
V2G	Vehicle-to-Grid

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Appendices

Appendix A

Figures

Figure 11

Smart buildings as systems within the whole smart grid [34]

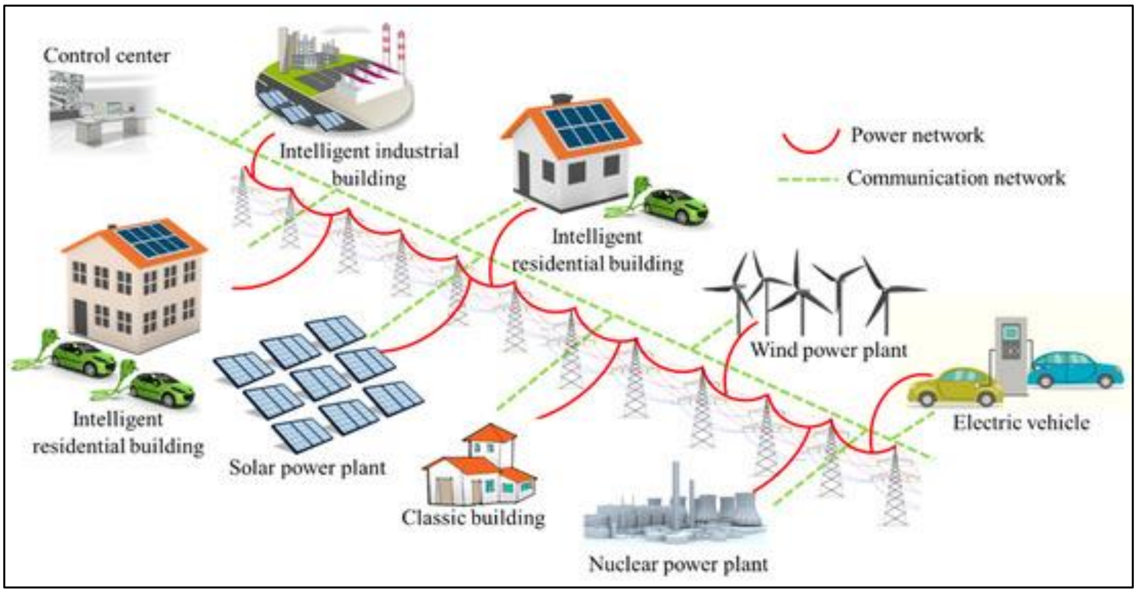


Figure 12

Some of the DRPs [34]

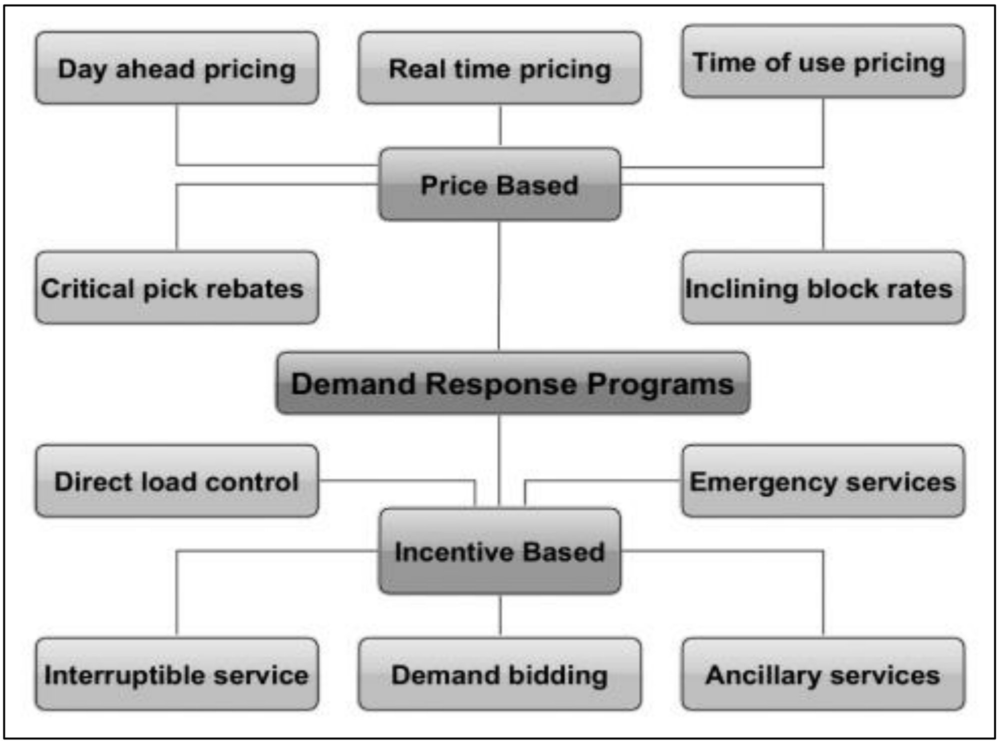


Figure 13

Smart building-integrated photovoltaic systems [34]

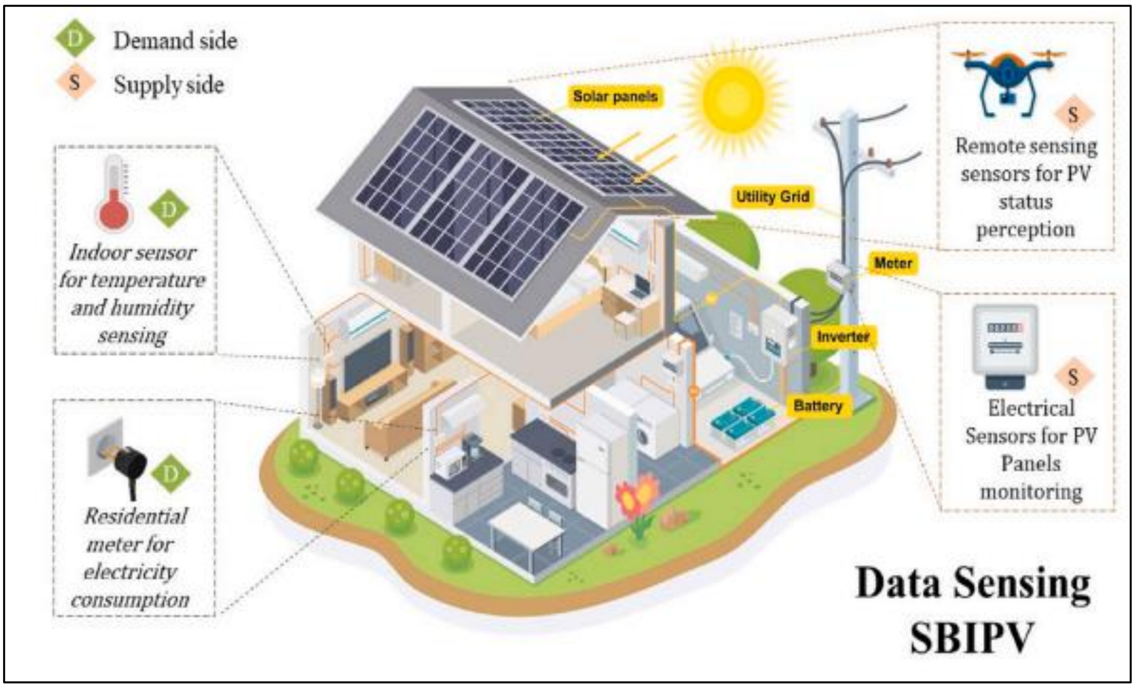


Figure 14

Building energy management [34]

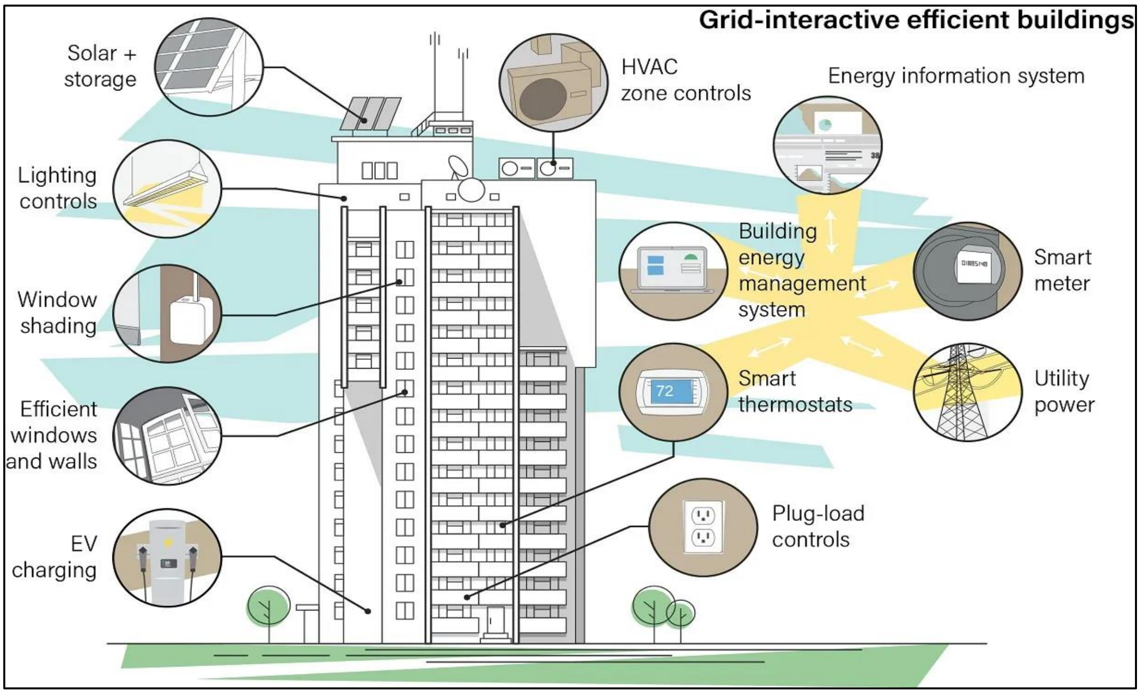


Figure 15

Cooperative Distributed Home Energy Management Systems [34]

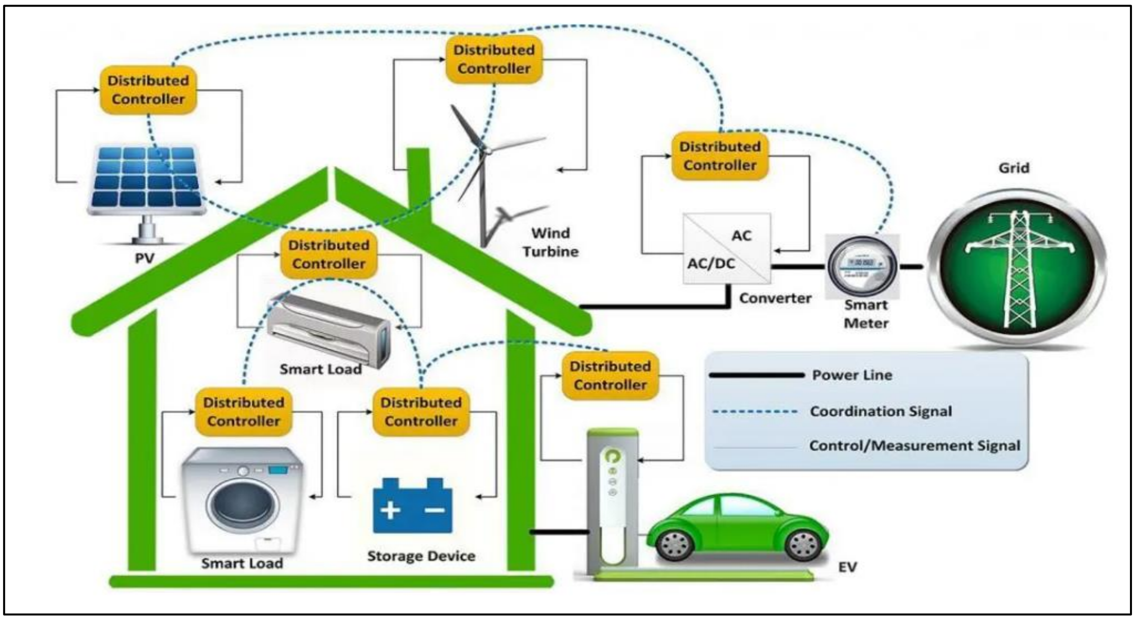


Figure 16

V2G technology [35]

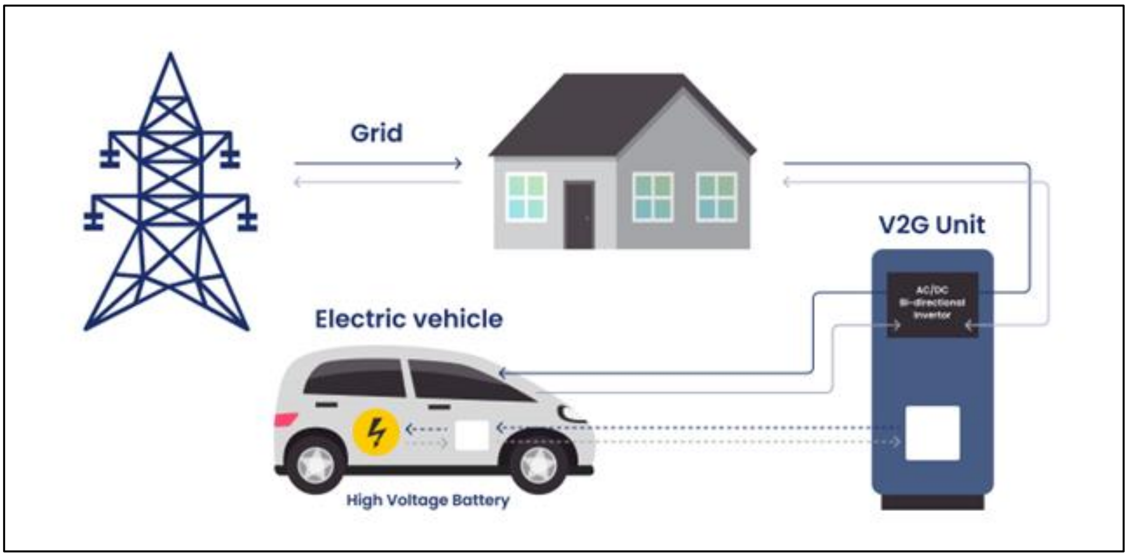


Figure 17

Vehicle-to-load-V2L.Smart EV chargers work with solar charging [35]

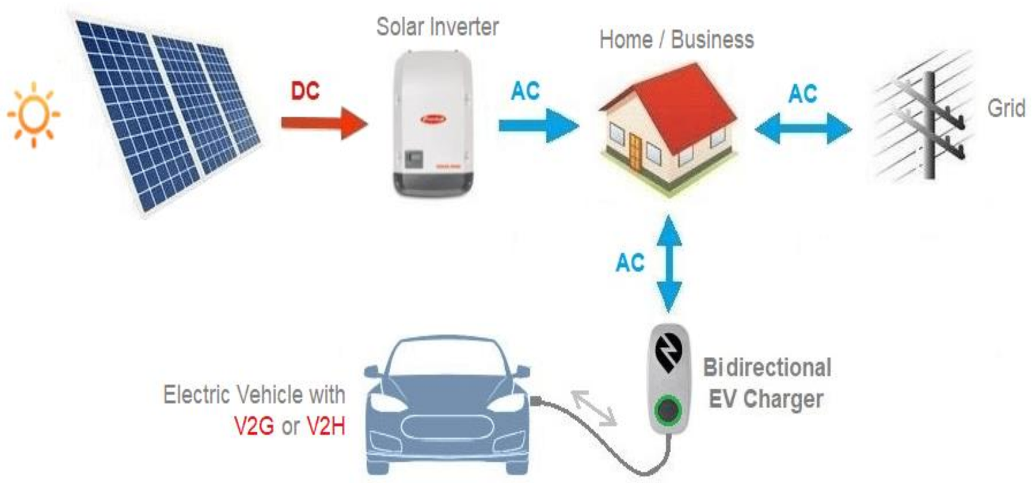


Figure 18

Schedule entered to the Simulation Software (DesignBuilder)

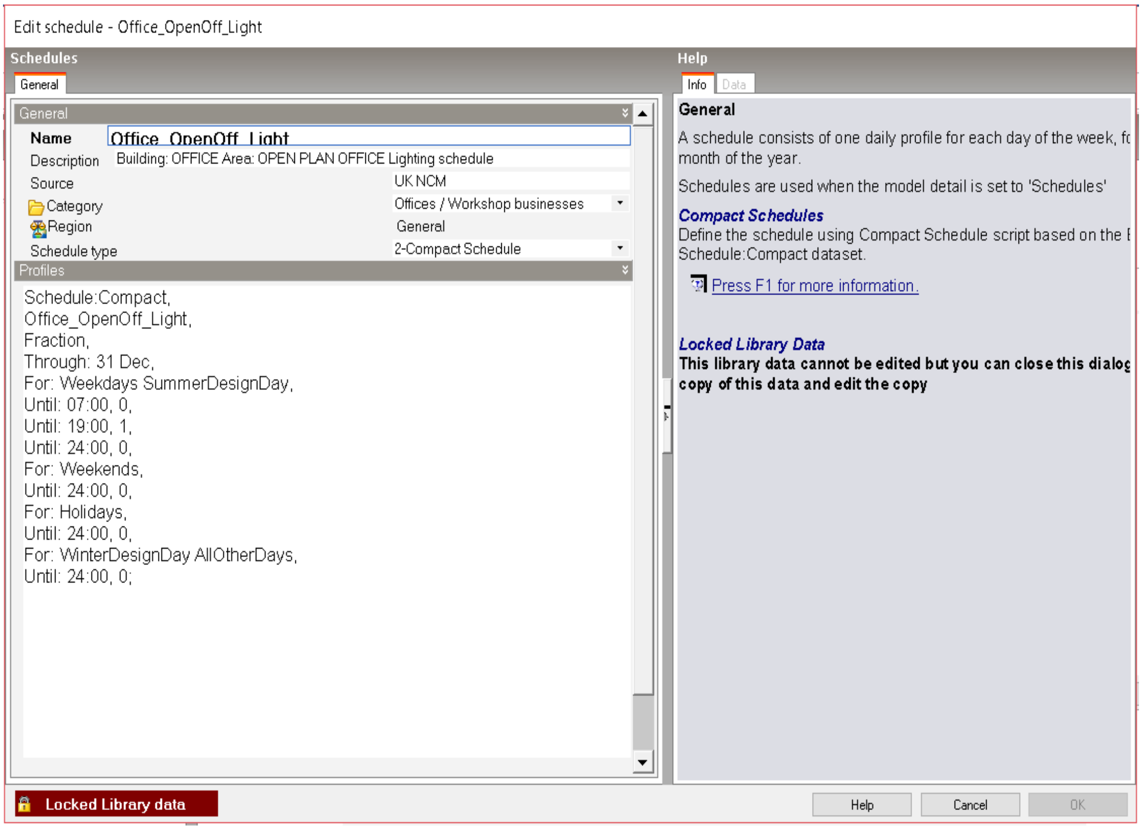


Figure 19

Linear control

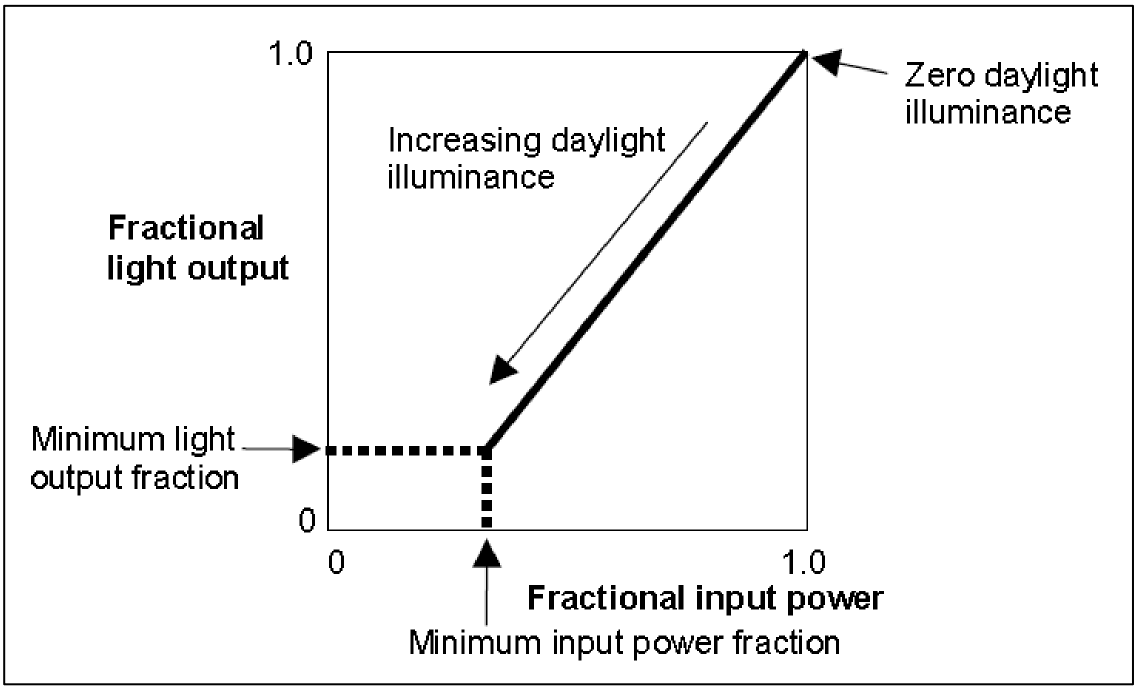


Figure 20

Electrochromic Glass [42]

Figure 21

External Louvers and Shading Devices [35]

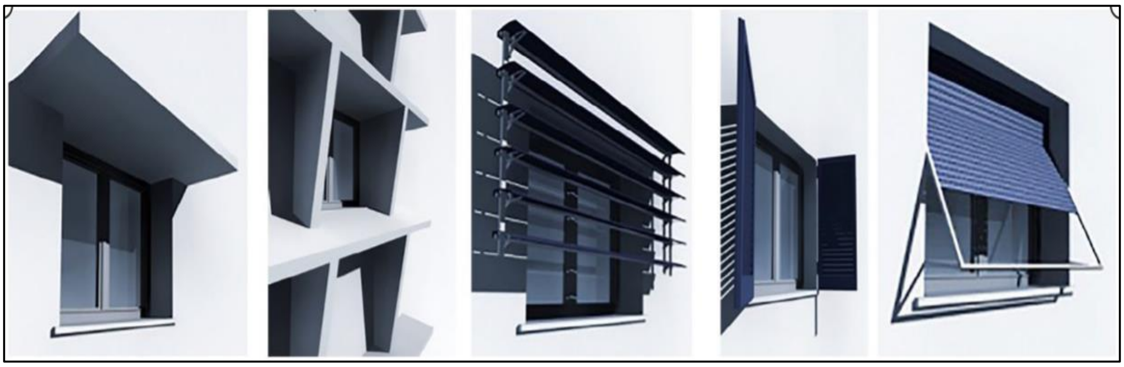
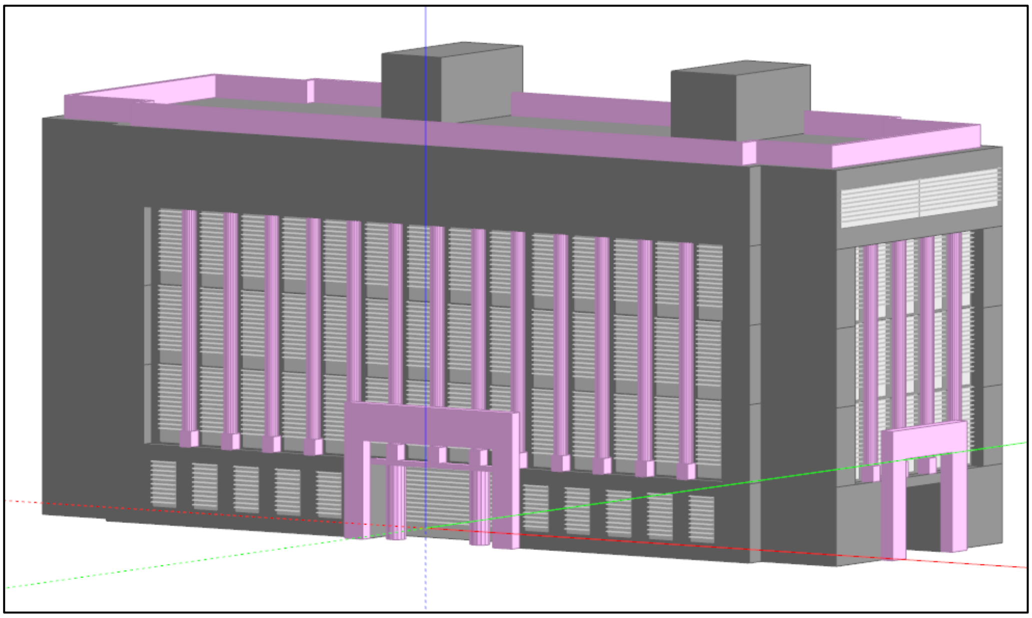


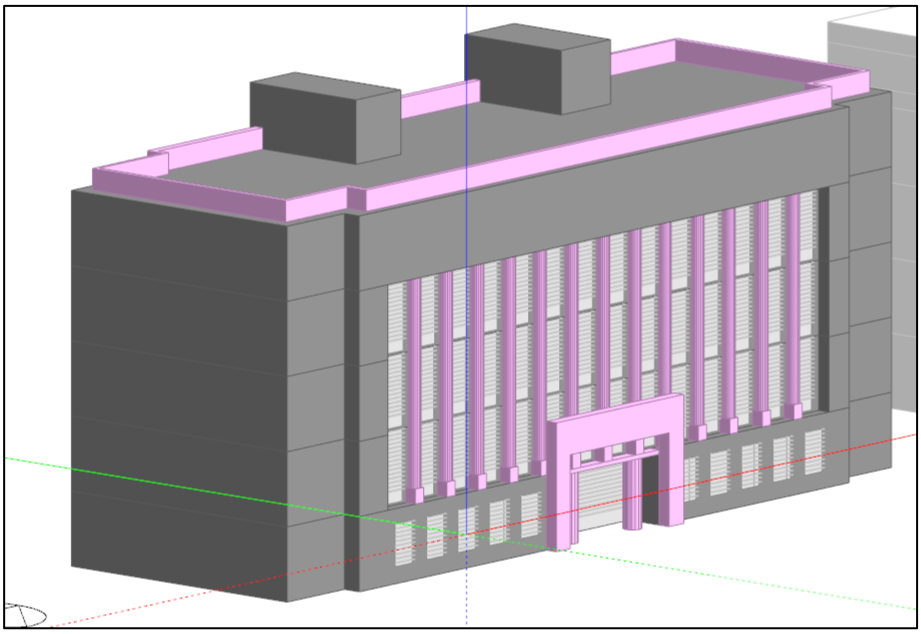
Figure 22

Motorized Blinds [35]

Appendix B

The exterior appearance of the building model as built in the simulation software, and some samples of simulation results





Analysis | Summary | Parametric | Optimisation + UA/SA | ASHRAE 90.1 | Data Visualisation

Program Version:**EnergyPlus, Version 9.4.0-217a24fc09, YMD=2024.06.19 14:08**

Tabular Output Report in Format: **HTML**

Building: **Building**

Environment: **UNTITLED (15-01:31-12) ** Jerusalem-Atarot AP - ISR MSI WMO#=401840**

Simulation Timestamp: **2024-06-19 14:33:23**

Report: **Annual Building Utility Performance Summary**

For: **Entire Facility**

Timestamp: **2024-06-19 14:33:23**

Values gathered over 8424.00 hours

WARNING: THE REPORT DOES NOT REPRESENT A FULL ANNUAL SIMULATION.

Site and Source Energy

	Total Energy [kWh]	Energy Per Total Building Area [kWh/m2]	Energy Per Conditioned Building Area [kWh/m2]
Total Site Energy	228043.96	77.36	77.36
Net Site Energy	228043.96	77.36	77.36
Total Source Energy	708407.34	240.32	240.32
Net Source Energy	708407.34	240.32	240.32

Site to Source Energy Conversion Factors

	Site=>Source Conversion Factor
Electricity	3.167
Natural Gas	1.084
District Cooling	1.056
District Heating	3.613
Steam	0.250
Gasoline	1.050
Diesel	1.050
Coal	1.050
Fuel Oil No 1	1.050
Fuel Oil No 2	1.050
Propane	1.050
Other Fuel 1	1.000
Other Fuel 2	1.000

Building Area

	Area [m2]
Total Building Area	2947.83
Net Conditioned Building Area	2947.83
Unconditioned Building Area	0.00

End Uses

	Electricity [kWh]	Natural Gas [kWh]	Gasoline [kWh]	Diesel [kWh]	Coal [kWh]	Fuel Oil No 1 [kWh]	Fuel Oil No 2 [kWh]	Propane [kWh]	Other Fuel 1 [kWh]	Other Fuel 2 [kWh]	District Cooling [kWh]	District Heating [kWh]	Water [m3]
Heating	1.47	6628.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cooling	67323.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interior Lighting	18865.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exterior Lighting	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interior Equipment	122871.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exterior Equipment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fans	12176.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pumps	176.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat Rejection	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Humidification	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat Recovery	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Water Systems	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Refrigeration	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Generators	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total End Uses	221415.11	6628.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Note: Natural gas appears to be the principal heating source based on energy usage.

End Uses By Subcategory

	Subcategory	Electricity [kWh]	Natural Gas [kWh]	Gasoline [kWh]	Diesel [kWh]	Coal [kWh]	Fuel Oil No 1 [kWh]	Fuel Oil No 2 [kWh]	Propane [kWh]	Other Fuel 1 [kWh]	Other Fuel 2 [kWh]	District Cooling [kWh]	District Heating [kWh]	Water [m3]
Heating	General	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Boiler	0.00	6628.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Boiler Parasitic	1.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cooling	General	67323.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interior Lighting	General	18865.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exterior Lighting	General	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interior Equipment	General	122871.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exterior Equipment	General	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fans	General	12176.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pumps	General	176.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat Rejection	General	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Humidification	General	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat Recovery	General	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Water Systems	General	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Refrigeration	General	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Generators	General	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Normalized Metrics

Utility Use Per Conditioned Floor Area

	Electricity Intensity [kWh/m2]	Natural Gas Intensity [kWh/m2]	Gasoline Intensity [kWh/m2]	Diesel Intensity [kWh/m2]	Coal Intensity [kWh/m2]	Fuel Oil No 1 Intensity [kWh/m2]	Fuel Oil No 2 Intensity [kWh/m2]	Propane Intensity [kWh/m2]	Other Fuel 1 Intensity [kWh/m2]	Other Fuel 2 Intensity [kWh/m2]	District Cooling Intensity [kWh/m2]	District Heating Intensity [kWh/m2]	Water Intensity [m3/m2]
Lighting	6.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HVAC	27.03	2.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other	41.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	75.11	2.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Utility Use Per Total Floor Area

	Electricity Intensity [kWh/m2]	Natural Gas Intensity [kWh/m2]	Gasoline Intensity [kWh/m2]	Diesel Intensity [kWh/m2]	Coal Intensity [kWh/m2]	Fuel Oil No 1 Intensity [kWh/m2]	Fuel Oil No 2 Intensity [kWh/m2]	Propane Intensity [kWh/m2]	Other Fuel 1 Intensity [kWh/m2]	Other Fuel 2 Intensity [kWh/m2]	District Cooling Intensity [kWh/m2]	District Heating Intensity [kWh/m2]	Water Intensity [m3/m2]
Lighting	6.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HVAC	27.03	2.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other	41.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	75.11	2.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

PERFORMANCE

Zone Summary

	Area [m2]	Conditioned (Y/N)	Part of Total Floor Area (Y/N)	Volume [m3]	Multipliers	Above Ground Gross Wall Area [m2]	Underground Gross Wall Area [m2]	Window Glass Area [m2]	Opening Area [m2]	Lighting [W/m2]	People [m2 per person]	Plug and Process [W/m2]
BLOCK1:ZONE6	9.60	Yes	Yes	33.60	1.00	15.27	0.00	0.00	0.00	7.5000	9.01	11.7700
BLOCK1:ZONE7	7.49	Yes	Yes	26.21	1.00	19.83	0.00	0.00	0.00	7.5000	9.01	11.7700
BLOCK1:ZONE10	19.17	Yes	Yes	67.09	1.00	13.83	0.00	3.90	4.38	7.5000	9.01	11.7700
BLOCK1:ZONE9	25.25	Yes	Yes	88.39	1.00	26.20	0.00	4.29	4.78	7.5000	9.01	11.7700
BLOCK1:ZONE8	6.35	Yes	Yes	22.23	1.00	0.00	0.00	0.00	0.00	7.5000	9.01	11.7700
BLOCK1:ZONE13	7.91	Yes	Yes	27.69	1.00	7.00	0.00	0.00	0.00	7.5000	9.01	11.7700
BLOCK1:ZONE12	21.16	Yes	Yes	74.06	1.00	18.40	0.00	2.49	2.92	7.5000	9.01	11.7700
BLOCK1:ZONE11	33.02	Yes	Yes	115.57	1.00	23.80	0.00	6.51	7.58	7.5000	9.01	11.7700
BLOCK1:ZONE5	18.57	Yes	Yes	64.98	1.00	20.09	0.00	2.36	2.78	7.5000	9.01	11.7700
BLOCK1:ZONE14	17.52	Yes	Yes	61.32	1.00	10.56	0.00	3.13	3.44	7.5000	9.01	11.7700
BLOCK1:ZONE4	298.70	Yes	Yes	1026.78	1.00	179.42	0.00	59.46	63.47	7.5000	9.01	11.7700
BLOCK1:ZONE3	17.84	Yes	Yes	62.45	1.00	8.75	0.00	2.79	3.28	7.5000	9.01	11.7700
BLOCK1:ZONE2	22.84	Yes	Yes	79.93	1.00	11.20	0.00	4.46	5.01	7.5000	9.01	11.7700
BLOCK1:ZONE1	80.86	Yes	Yes	283.00	1.00	66.10	0.00	9.72	10.65	7.5000	9.01	11.7700
BLOCK2:ZONE1	574.23	Yes	Yes	2009.79	1.00	405.23	0.00	123.82	134.34	7.5000	9.01	11.7700
BLOCK4:ZONE1	574.23	Yes	Yes	2009.79	1.00	405.23	0.00	126.30	136.87	7.5000	9.01	11.7700
BLOCK7:ZONE3	559.50	Yes	Yes	1958.24	1.00	374.22	0.00	73.92	79.07	7.5000	9.01	11.7700
BLOCK7:ZONE1	18.79	Yes	Yes	65.77	1.00	11.34	0.00	4.70	4.70	7.5000	9.01	11.7700
BLOCK7:ZONE2	20.41	Yes	Yes	71.44	1.00	11.34	0.00	4.70	4.70	7.5000	9.01	11.7700
BLOCK8:ZONE1	20.04	Yes	Yes	60.13	1.00	55.59	0.00	2.70	2.98	7.5000	9.01	11.7700
BLOCK9:ZONE1	20.12	Yes	Yes	60.37	1.00	57.24	0.00	2.70	2.98	7.5000	9.01	11.7700
BLOCK3:ZONE1	574.23	Yes	Yes	2009.79	1.00	405.23	0.00	123.64	134.15	7.5000	9.01	11.7700
Total	2947.83			10278.64		2145.86	0.00	561.60	608.07	7.5000	9.01	11.7700
Conditioned Total	2947.83			10278.64		2145.86	0.00	561.60	608.07	7.5000	9.01	11.7700
Unconditioned Total	0.00			0.00		0.00	0.00	0.00	0.00			
Not Part of Total	0.00			0.00		0.00	0.00	0.00	0.00			

Comfort and Setpoint Not Met Summary

	Facility [Hours]
Time Setpoint Not Met During Occupied Heating	0.00
Time Setpoint Not Met During Occupied Cooling	60.67
Time Not Comfortable Based on Simple ASHRAE 55-2004	1380.17

جـامعـــة النجاح الوطنية
كليـــة الدراســـات العليـــا

أثر استخدام تقنيات المباني الذكية في تقليل استهلاك الطاقة في فلسطين

إعداد
محسن محمد حسني ابودياك

إشراف
د. معتصم بعباع

قدمت هذه الرسالة استكمالا لمتطلبات الحصول على درجة الماجستير في هندسة الطاقة النظيفة وترشيد الاستهلاك، من كلية الدراسات العليا، في جامعة النجاح الوطنية، نابلس– فلسطين.

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أثر استخدام تقنيات المباني الذكية في تقليل استهلاك الطاقة في فلسطين

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الملخص

يركز البحث في هذه الرسالة على إمكانات تقنيات البناء الذكية المختلفة في زيادة كفاءة الطاقة وترشيد الاستهلاك في المباني في فلسطين. وباستخدام برامج المحاكاة مثل DesignBuilder وEnergyPlus، تم اجراء دراسة شاملة لتأثير كل تقنية على إجمالي استهلاك الطاقة. ركز هذا البحث على أنظمة الإضاءة وأنظمة التظليل وأنظمة التدفئة والتهوية وتكييف الهواء. تم محاكاة كل من هذه التقنيات وتم إجراء أكثر من إجراء لكل تقنية، للوصول إلى أفضل تقنية وأفضل توفير للطاقة.

في أنظمة الإضاءة، تم استخدام أجهزة استشعار الإشغال وأجهزة استشعار الضوء الطبيعي والتحكم الخطي في أنظمة الإضاءة، ووجدت الدراسة أن استخدام هذه التقنيات يقلل من استهلاك الطاقة بنسبة 23% إلى 24%. في أنظمة التظليل، تم استخدام الستائر الداخلية الذكية والأفلام الذكية والفتحات الذكية، وكان معدل التوفير 26%، كما أظهرت النتائج. في أنظمة التدفئة والتهوية وتكييف الهواء، تم استخدام التقنيات الذكية مثل الموفرات الذكية واستعادة الحرارة، ووجد ان معدل التوفير يتراوح بين 2% إلى 6%. وتوضح هذه النتائج الفائدة الكبيرة لاستخدام هذه التقنيات في تقليل استهلاك الطاقة وزيادة كفاءة الطاقة وتحقيق ترشيد الاستهلاك.

كما أوضحت الدراسة تقنيات وأساليب أخرى من شأنها أن تساهم في تحقيق المباني الذكية المتكاملة، ومنها دمج المباني الذكية مع الشبكة الذكية، مما يزيد من مرونة الشبكة ويزيد من موثوقيتها. وكذلك دمج أنظمة الطاقة الكهروضوئية مع المباني الذكية. وكذلك دمج المركبات الكهربائية مع المباني الذكية، والتي من خلالها يمكن تلبية الطلب على الطاقة في المبنى خلال فترات الذروة من خلال نقل الطاقة من البطاريات

إلى المبنى. الصيانة التنبؤية في المباني الذكية، واستخدام الصيانة التنبؤية يقلل من الطاقة المهدرة في المبنى ويحسن من طرق صيانة وإدارة المباني.

تسلط الدراسة الضوء على الإمكانات التي يمكن أن تحققها التقنيات الذكية والأنظمة المتكاملة مع المباني الذكية من حيث تقليل الاستهلاك وتحقيق الاستدامة وراحة شاغلي المباني، مما يمكن أصحاب المباني من تحقيق وفورات كبيرة من استخدام هذه الأنظمة، وخفض تكاليف التشغيل، وانبعاثات الغازات المسببة للاحتباس الحراري.

تقدم هذه الأطروحة رؤى مهمة للمهندسين المعماريين وأصحاب المصلحة وصناع السياسات الساعين إلى تنفيذ حلول كفاءة الطاقة وترشيدها في المباني الفلسطينية. كما يساعد في فهم أوسع لتطبيقات المباني الذكية في مجالات متنوعة وظروف بيئية متشابهة، ويشجع هذا البحث على تبني التقنيات الحديثة لمواكبة الموجة العالمية من حلول الطاقة ويشجع على المضي قدمًا لإيجاد حلول أخرى والمضي قدمًا نحو مستقبل أكثر استدامة.

الكلمات المفتاحية: المباني الذكية؛ كفاءة الطاقة؛ أجهزة الاستشعار ؛ التقنية الذكية