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A Survey of Using Internet of Things to Enhance Zero Energy Buildings

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Abstract:With the development of the Internet of Things (IoT) technology, people have higher requirements for quality of life, and they have put forward higher requirements for visualization and intelligence for various environmental indicators of the house. Buildings are one of the largest energy consumers. Renewable energies, in addition to electricity networks, can be employed to meet the energy demands of buildings. Building energy consumption could also be managed using intelligent systems such as the Internet of Things (IoT) and wireless sensor technologies. Luckily, combining renewable energy sources with these sophisticated technologies allows for the construction of nearly zero-energy structures. Therefore, in this research article, we will highlight the Internet of Things (IoT) network that interconnected computing devices and technologies with the goal of enhancing efficiency in energy use in both residential and commercial buildings. To properly appreciate the application of IoT to increase energy efficiency in buildings, a thorough review of a plethora of empirical surveys and research will conduct. A modern overview of the current research also looks into how these technologies might be improved furthermore required solutions should be provided. The majority of the research we looked at focused on the applicability of various components of IoT to a given application.

Key words: Internet, Internet of Things (IoT) technology, Renewable energies, zero-energy structures, Buildings, electricity networks, wireless sensor technologies

I. Introduction:

Buildings are a major source of energy use. Renewable energies, in addition to electrical networks, can be employed to meet building energy needs. Intelligent systems, for example, The Internet of Things (IoT) and wireless sensing technologies could be used to control building energy consumption [1]. Fortunately, combining renewable energy with these sophisticated technologies allows for the construction of practically zero-energy buildings[2].The European Union's significant targets for reducing the energy consumption in the built environment set for the near future, as well as the achievement of Zero Energy Buildings (ZEB) [3], also pass through intelligent resource optimization, capable of providing the best environmental health, safety and comfort conditions while enhancing resource efficiency, due to the ability to associate environmental factors and exact needs [4].

Building Automation Systems (BAS) are proving particularly successful in this framework: their demand is continually and gradually increasing, thanks to the market debut of numerous devices suitable to specific components of the home technological system. Based on Wi-Fi data transfer, they allow you to practically have your house at your fingertips, with no need for wiring or retrofitting current equipment. (BAS) are Contentment, safety, carbon emissions reduced, flexibility and ease of use are starting to grow needs for building occupants, and the usage for intelligent "Building Automation Systems" to meet them is increasing [5]. The transformation of the huge network of web-connected, smartphone-controlled common objects is known as the "Internet of things" (IoT) [6]. All actual building sub-systems (electrical distribution, heating and cooling, drainage system, lighting, network device, remote access, elevator control, fire detection, and alarm systems, sustainability and energy storage, mobility, and transport) can become part of a specific centralized system capable of learning users' behavior and preferences, anticipating solutions, or providing them [7].

The above systems employ accurate forecasts, efficiency, and algorithms for analyzing that collect information in real-time from sensors and meters strategically positioned throughout the building and automatically identify internal microclimate specifications, living quarters, and ICT infrastructure that have been used, participation, weather information, and energy efficiency. The system recommends methods to help building managers optimize energy use analyzes of the input information; users, nevertheless, can participate in the system as active participants [8]. Monitor usage on a real-time basis, using a tablet or smartphone, and they will change their conduct as a result, becoming agents of self-preservation Smart homes, depending on the type of technology employed, Appliances can operate somewhat autonomously set and programmed reactions to external stimuli parameters) or completely autonomous programmed functions, which are based on dynamic reactions to environmental factors Self-learning programs are those that can be created or enhanced. Building Integrated Automation Systems are not the only thing that can be automated Building energy usage may now be reduced using a new generation of low-cost sensors that are connected to the Internet. These systems may be used in any type of structure and can automatically monitor internal environmental factors as well as energy usage of particular appliances or power sockets, giving users real-time information on personal smartphones, no matter where they are on the globe. Sending email or SMS alerts, as well as eventual warning or process failure warnings, are all part of the service [8], [9].

In associated with data collection, most of these systems enable real-time control of residential equipment and machines via smartphone, with the ability to create on-off schedules and modify activity levels as required. Because of their capacity to transmit data with themselves and collect aggregate data from other devices, devices become auto recognizable and intelligent [10]. Smart alarm clocks anticipate traffic, when it's time to water, plants alert the watering system, home automation systems route the inflow and outflow of inhabitants to make temperature adjustments as needed, and intelligent lighting self-switches on after a lengthy period of absence for security. By connecting to the Internet, all things may play a proactive role. The Internet of Things' objective is to have the electronic world create a map of the actual world, offering an electronic representation of the real world [10], [11]. In this paper, an introduction to the ZEB concept has been viewed. The rest is organized as follows: The performance of a building's structural components has a significant impact on its overall performance as a result; yearly energy consumption will be affected [12], [13]. In addition to the significance of performing a building site survey Standards, recommendations can assist engineers and technicians in identifying previously unknown information about heat transfer coefficients and thermo physical characteristics. Can standards recommendations, on the other hand, be regarded as credible in each case? Section 1. aims to answer this topic by discussing several recent studies and suggesting systematic methods. In addition, the latest developments used in ZEB. In Section 2. Illustrated and classified existing systems to enhancement the ZEB using IoT. At last, conclusions have been presented in Section 3

II. Literature Review of ZEB Development

There are lots of articles that the latest developments that have taken place in buildings in terms of building structure, materials used in construction, windows, etc., renewable energy sources, for example solar cells and others, as well as challenges and problems that could impede the efficient use of energy the best way. In addition, by literature review, it can be understood that many papers considered existing methods from different aspects.

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In [14] present a methodical approach to creating near-zero-energy community buildings by evaluating the energy efficiency of integrated passive and active solutions, as well as renewable energy systems. The amount of energy used for heating, cooling, and lighting was reduced by about 20%. To reduce the amount of energy used for residential heated water, several renewable energy technologies, such as solar panels, solar thermal panels, and geothermal pumping systems, were examined and its performance assessed. The combining of the Photovoltaic system with extra PV modules and the hydrothermal system was selected for achieving the virtually zero energy objective after comparing results of their building energy. The use of solar thermal systems enabled the near-zero energy objective to be achieved. The life-cycle cost analysis (LCCA) of net-zero energy buildings (NZEBs) in U.S. climate locations is presented in [8]. The physics-based variable refrigerant flow (VRF) heat pump (HP) model developed in Energy Plus was taken into consideration for NZEB design. By assuming that smart metering was accessible to the electrical grid, the distributed solar PV power plants were connected directly to the building's electrical operating system. It should be emphasized that high-efficiency technologies, such as a VRF system, may be used to allow NZEBs effectively. However, because the proposed system was included the various impact on economic efficiency under particular circumstances, suitable hypotheses such as the same study period, economic base data, and renewable programs must be fully reviewed during the early stages of design. In addition, such LCC results from this study can help determine the relative cost-effectiveness of mutually exclusive alternatives by accepting the alternative with the lower LCC of VRF models for commercial NZEBs in various U.S. weather conditions. In [15] presented a novel "double zero" built environment concept, in which the "first zero" refers to zero heat gain/loss through building envelopes, while the "second zero" refers to net-zero energy usage to achieve the "first zero". A novel composite building envelope system was suggested with the combination of photovoltaic (PV), thermoelectric (TE), and battery systems with the envelope structure by establishing the aim of "double zero". The "first zero" is achieved by TE cooling/heating, which uses PV or battery power to regulate internal heat flux. Model predictive control (MPC) of power flow with battery charge optimization produce the "second zero". With a mix of analytical and numerical approaches, a system model was developed and verified against empirical observations in both summertime and wintertime circumstances. The study [16] offers a thorough overview of energy efficiency methods for fresh air delivery, encompassing theoretical, practical, and simulation studies, in order to pave the path for future work in fresh supply air techniques for zero energy buildings. Various renewable conservation solutions for fresh air delivery in buildings are analyzed and discussed for their pros and cons, economic, and climatic adaptability. After that, fresh air delivery technologies' difficulties and future research objectives are explored. In [17] offers a comprehensive design strategy for residential net-zero energy buildings (NZEBs) that incorporates the Triple Bottom Line (TBL) principles of social, environmental, and financial sustainability. The social requirement is matched to personal comfort and environment interaction (temperature and humidity from natural cooling and visual comfort from natural lighting); the environment need is associated with energy efficiency; and the financial need is routed to life cycle cost (LCC). Multi-objective improvements are carried out in two stages: the first improves the pace of natural cooling and day lighting, while the second enhances energy consumption and LCC.

Sensitivity analysis is used to determine which factors in the optimization procedure are the most important. The method is used to build residential NZEBs in Singapore, a tropical nation. The feasibility of constructing residential NZEBs in Singapore is assessed using two common residential construction types: landed houses and apartment buildings. A renewable energy system's (RES) necessary capacity is determined. A study [18] centered on examining the techno-economic performance of real-world ZEH implementations in Japan. To begin, the current technical break through and integrated smart management techniques for optimizing the cost or energy-saving performance of ZEHs were introduced. Then, based on the power of self-sufficiency and dynamic power balancing, presented the sustainable operations of four typical ZEHs. The major goal of this research [19] is to assess the feasibility of pre-cooling ventilation system using a ground-to-water heat pipe in conjunction with an intermediary water-to-air exchanger during in the summer using empirical values.

An existing virtually zero energy building in Benevento, a middle-sized city in South Italy with a typical Mediterranean weather, serves as the study includes for this inquiry. Several performance metrics were measured using four distinct HVAC setups.

C1: The aeraulic heat pump offers ventilation, heating, and cooling, but it does not pre-cool the outside air.

C2: It works in the same way as the first, but it also allows you to pre-cool any external ventilation system before it enters the pump.

C3: The geothermal heat exchanger, in conjunction with the air-to-water heat exchanger, provides for pre-cooling of the airflow in this arrangement.

C4: Excluding the pre-cooling of the exterior ventilation air, it is identical to the third.

For the predicted schedule and real-time optimum management of energy systems in zero/low energy buildings, a coordinating online multi-objective optimal control approach formed by two control optimization techniques is presented [20]. For online multi-objective optimization of both predictive scheduling and real-time optimum control, a cooperating game theory technique is used. Under two typical working situations, this control method was tested and assessed on energy systems with battery bank in a grid-connected building. By using a complete methodology for the designing, building, and monitoring of NZE settlements established in the EU Horizon 2020 ZERO-PLUS project [21], this paper examines the benefits and challenges relating to the implementation of the net zero energy (NZE) idea at a settlement scale.

Four case studies were used to test the concept. The ZERO-PLUS method is given first, followed by an examination of the accompanying benefits and obstacles encountered. Following that, stakeholder analysis is used to determine the responsibilities of various stakeholders engaged in the process. Finally, new dynamics develop that are important for the proper implementation of NZE agreements.

The researchers in [22] introduced a study was aimed to identify the technical, organizational, and social problems of creating NZE structures, to recognize the relevance of public awareness in the construction of NZE dwellings, and to make recommendations on how to increase public awareness. The primary data was collected using a qualitative approach, which included a survey and interviews. According to the findings, the construction of NZE buildings has a number of obstacles, including technical concerns, a lack of governmental and institutional support, and a lack of standardization. Buildings are one of the most important causes of carbon dioxide emissions that cause climate change. Although it is a simple concept, there is no valid global definition and this is the most important challenge for energy systems in buildings that need appropriate treatment. The study in [13] reviewed and summarized the current and comprehensive definitions of ZEB and then analyze the differences in the current definitions. The reason for the various definitions is due to the following:

- Policy differences
- Researchers' opinions
- Owner's interest
- Investors' profits

It should be noted that the definition of ZEB has an effective impact on the design of the building and the way to achieve the goal. The research also dealt with the examination and identification of ZEB GOALS, as well as reducing the demand for energy and the emission of greenhouse gases from the construction sector. The government should issue legislation on the use of energy for homes. In the last part of the research, a good map of ZEB was drawn reducing energy demand by implementing various energy efficiency measures to generate renewable energy to obtain sufficient balances for balance. The main problems to achieve the goal are rising prices of urban land and high-efficiency equipment in addition, the problems that distributed generation (power generation and distribution) produce on the stability of the grid. Finally, suggestions were made regarding the appropriate definition from four perspectives

Energy carbon economy EXERGY. The proposal is to design a new building in ZEB, and we determine in which category it falls.

The European Union aims to put in place a law requiring new buildings to meet the requirements of the NZEB by 2030, and of course, this decision covers technology based on international standards-compliant ideas [23]. The goal of this study is to use NET ZEB to review publications, based on building density and analyze the possibility of applying this study to nine adjacent residential neighborhoods in Belgium. The main considerations in this research are weather change, building renovation, solar panels, and renewable mobility.

This study demonstrates that the present levels of energy use in the Walloon area of Belgium may be estimated, and many techniques for improving efficiency have been offered. The most effective work tools were highlighted on a neighborhood scale, As a result of these research, the inadequate insulation of buildings in the Walloon region as a result of outdated construction materials was revealed. There are new ways to reduce energy consumption, for example

1- Installing photovoltaic panels, especially in rural and semi-urban areas, while in urban areas Due to the influence of shadows, this approach is less effective.

2- Reducing the distance traveled or increasing the electric vehicles (cars, trains, etc.) in the city is a fantastic method to save energy. The same conclusions can be applied compared to comparable European nations with similar climates and building stock. The decrease in the energy consumption of neighborhoods in terms of buildings and daily commuting in 2040 compared to 2012 is likely to reach 5.69% due to the reduction of distance traveled by 20%, and energy consumption by 6.48 % due to climate change, and 12.95% due to the rate Annual building renovation and 18.79%-100% due to electric cars, 22.62% due to building renovation rate doubled, 31.62% due to light building renovation rate, 63.25% due to complete building renovation, and 6.53 percent due to Install solar panels with an area of 20 square meters on the roof of residential buildings. Finally, we conclude that energy consumption can be reduced to more than 90 percent on a neighborhood scale in terms of buildings and daily commuting by integrating the complete renovation of all buildings, electric cars, and photovoltaic panels. This script helps you to achieve the goal of net ZEB on a neighborhood size.

III. Zero Energy Buildings Collaboration with Internet of Things

The Internet of Things (IoT) is transforming various applications and industries, smart houses, smart buildings, and green buildings are just a few examples, into fully automated processes. Smart grids, smart cities, and e-health are all examples of smart technologies. The researcher in [24] introduced studies about the function of the Internet of Things (IoT) in real-time regulating and monitoring of parameters like tilt angles and defective modules in building integrated photovoltaic (BIPV) systems. IoT is also described for maximum power harvesting from BIPV modules on roofs and facades. A BIPV installation that uses IoT makes the system more cost-effective and reliable. It can also be handled remotely using android apps on smartphones or laptops and tablets via the internet, which has been more accessible in recent years. A new approach in smart generation from renewable energy resources, such as solar, is emerging with the help of the Internet of Things (IoT) and (BIPV). In [25] a systematic review of some of the common and applied artificial intelligence techniques to assess the stability of the power grid, predict the loads, and detect safety problems and faults in the smart grid and power systems. The smart grid allows the collection of very large amounts of data with multiple dimensions and types about the operations of the electric power grid by integrating control, communication and infrastructure technologies.

One of the most important challenges

- Information (data) privacy and security
- Dealing with the black box aspect of some artificial intelligence approaches in order to create artificial intelligence solutions with a human-centered perspective.

Finally, the following was concluded:

- The application of artificial intelligence techniques too many fields is very important for the reliability and flexibility of the network.
- There are many challenges that limit additional applications for smart cities.
- Artificial intelligence applications have been utilized to increase the resiliency and dependability of smart grid systems.

In [26] the researcher discuss in there study the Nearly Zero Energy Building (NZEB) aim (Directive, 2010/31/EU and 2018/844/UE) was introduced by European energy policy to encourage the energy transition of the building sector. Positive Energy Building (PEB) is a form of NZEB that is promoted by EU projects such as Horizon 2020.

The European Union's primary initiatives in support of the NZEB and PEB design models have been critically reviewed based on the most recent advancements. We have also added a section on innovative materials and technologies such as PCM and VIP (smart glass, integrated photovoltaic systems).[27] It is critical to design for energy efficiency since faults to waste energy would have an impact on the building's running costs over the course of its life. The opening safety on the facade should be designed to match their needs in order to maximize natural sunlight. Reduce the quantity of solar heat that enters a room through the mechanisms of radiation, conductivity, or convection, maximize the use of skylights, and shadow the building's skin with structural elements to save energy. Building a home involves careful planning that considers a variety of elements, such as the physical potential.

The physical capacity of a property is determined by factors such as construction materials, geographical features, and temperature. Climate change is the greatest issue that must be handled in the current era due to modern-day global warming. The purpose of building design, particularly in residential housing, is to provide facilities for the tenants. Utilities are achieved through comfort ability, such as positional comfort, thermal comfort, aural comfort, or lighting quality.

Wasted energy can also be a result of poorly integrated or even incorrect building designs that are not responsive to factors such as use, function, or climate. This is made worse by the designers' proclivity for emphasizing purely aesthetic factors (prevailing trends). Although its application has not yet been found considerably, green concepts and energy consumption efficiency in the housing industry as a response to global warming are already familiar in Indonesia. Housing developers' green initiatives are frequently just marketing gimmicks that never materialize, leaving it up to the community to take care of what has left. Rather than promoting true green living, house developers instead promote lovely and green living environments. The PLUG-N-HARVEST architecture in [28] is dependent on cloud Artificial intelligence systems and security -by-design Internet of Things networks to control constructions with almost minimal ADBE in both residential and commercial structures. Three different real-world pilots in Germany, Greece, and Spain have been considered to illustrate the PLUG-N-HARVEST architecture. There is an article in the journal about a residential building IoT pilot in Spain that uses Zwave technology to enable plug-and-play deployments of IoT wireless networks (such as sensors and actuators). Building equipment and cloud management systems communicate securely because security is built in from the start. Furthermore, the outcomes of intelligent cloud management show an improvement in energy consumption as well as comfort levels. The main objective of this research[29] is to review and analyze the efficiency of applications based on artificial intelligence, especially in BEE, with a focus on implementing ZEB easily, taking into account the impact and behavior of individuals who occupy buildings. This paper provides details of artificial intelligence-based methods for building zero-energy buildings and we analyze the individuals who occupy these buildings and their behaviors. Current research trends depend on:

- Analyzing the changes that may occur to the approach based on artificial intelligence that are related to laws and standards and can be considered an important and more influential factor for BEE.
- The main directions of the AI-based approach to building infrastructure have also been reviewed and carefully compared.

  Studies have been conducted for applications based on artificial intelligence for smart buildings from the following aspects:
- Control and discovery of the internal environment
- Multi-energy efficiency of buildings
- Predictive accuracy of pregnancy and performance.

This study in [30] examines NZEB concepts for Northern European countries with a focus on Finland and extends the analysis to include Sweden, Norway and Estonia. The design concepts of various structures, as well as the usage of solar energy technology, have been considered. According to recent research that showed the important role of users (energy consumers within buildings), the researchers took into account user behavior in order to more accurately simulate the electricity consumption of household appliances and indoor heat gains. Many of the NZEB ideals, in reality, may be realized by depending on more energy-efficient building design principles or deploying on-site solar energy technology. Choosing the correct design concepts for a building depends on the topology and finding solar technologies based on the building's main heating source. Finnish passive design principles are adopted in Finland and Norway without the installation of renewable energy systems on site. If a ground source heat pump is utilized as the primary heat source, energy performance and passive design principles might lead to NZEB in Norway and Finland. In Sweden and Estonia the approved principle of construction and the primary heating source have been relied upon. To fulfill NZEB standards, various sizes of solar energy technology must be deployed on site. The energy generated in the northern latitudes with solar technologies is not enough to reach the NZEB target. The results confirmed that there is no single solution ready for ZEB. It also stressed the importance of taking into consideration the consumer dynamics, household appliances, and lighting energy requirements in order to obtain the best match between energy generation and use. This work [31] will present a study on the smart building system that relies on the new hybrid solar energy. The system consist of inventive photovoltaic-thermal-cooling (PVTC) plates incorporated with hot and cold stowage with bidirectional communication with electricity grid, hotness, and coldness networks. The suggested system is compared to a photovoltaic (PV) systems combined with battery and heat pump for a situation study intricate building in Denmark. A parametric research is used to compare the profitability and financial measures, as well as the influence of significant elements on each scenario. In addition, the circumstances of the ideal system and the size of the suggested system are determine by the genetic algorithm method, taking into account the initial cost and local energy networks were transferred. In this work, a comparison and evaluation of:

1. Matlab code development
2. For each scenario, performance characteristics and financial pointers for the equipment, including the primary cost, payback period, supplied energy, and energy acquired and supplied to and from the networks.

The results show that the initial cost of the proposed new system is 177,000 dollars for the first scenario, which contains a battery, and 283,000 dollars for the second scenario, which consists of a battery and a heat pump. The proposed new system has a lower return on equity of 6.6 years when compared to the first scenario's 9.9 years and the second scenario's 8.8 years, demonstrating the significant impact of eliminating the battery and heat water pump, as well as the two-way communication with the electricity, heat, and cold networks. The scattering of critical factors reveals that plate area and hotness stowage capacity are not sensitive characteristics, and that reducing the cold storing capacity to a minimum is a preferable technical and economic choice. In this study[32] looks at a group of technologies that can eliminate standby consumption across a wide range of electrical outlet loads. It also conducts in-depth research and prototype development on a number of alternative alternatives.

Burst and sleep transistors have already been proven the foundation of zero-standby systems.The next step is to look at how two different sorts of wake-up signals are put to use. The first is based on optical transmission and is suited for line-of-sight activated wireless devices including set-top boxes, ceiling fans, and controlled curtains. The second example comes from a wake-up radio, but it can be used to any wireless device in your home. In terms of standby power, there is no single solution that can handle everything.

A real-time NZEB[33] with bilateral wireless sensor and actuating system has been presented and constructed. With the support of IEEE 802.15.4 and IEEE 802.11 wireless networks, the proposed NZEB central computer collects and manages a database of on-site solar production, battery state - of - charge, and load power usage data of a building. The suggested system was set up as a test bed, with sensors, controller, actuator, and server modules interconnected via a bilateral wireless system architecture similar to that used in the Internet of Things. The experimental results test bed show that the created system can calculate on-site solar production, battery bank charging time, and load energy usage.

IV Conclusion:

Zero-energy buildings improve the energy efficiency and minimize building energy requirements, making them essential for long-term resource development. The growth of zero-energy buildings is still in its early stages, and there are a number of issues to be addressed, including a lack of government incentives, immaturity equipment and devices, insufficient training, and a lack of results of zero-energy buildings. To encourage the construction of zero-energy buildings in a stable and healthy manner.

The Internet of Things (IoT) age is arrived, defined by a plethora of "intelligent" items capable of connecting and interacting with one another. We could lower building energy usage while boosting environmental fellow human using this skill and the connection between things and individual requirements.

The Internet of Things could be especially valuable during maximum energy usage periods, allowing for more reasonable power usage management. Inside the building, all devices may communicate with others, interface with networks, and generate data about how much energy they use. After the data has been acquired, it may be used to begin making judgments about how to manage the entire system efficiently.

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