ART & TECHNOLOGY PUBLISHING PTE. LTD.

2024 Volume 2, Issue 1

Education Innovation Research

ISSN (Online): 3029-1852 ISSN(Print): 3029-1844

Towards Sustainability by IoT in Smart Buildings—Case Studies In China

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Abstract:

In recent years, a plethora of solutions have been facilitated by the Internet of Things (IoT) in smart buildings aimed at realizing dual-carbon goals and sustainable development. Despite a general emphasis on sustainability, existing IoT-based solutions typically focus on monitoring and managing energy consumption and generation. Based on comparative case studies of the Winter Olympics program, Haier Smart Home, and the energy recovery and management in Xiongan New Area respectively, our interest captures an expanded view of sustainability and provides Chinese solutions to achieve this goal.

Keywords:

Smart buildings

IoT

Sustainability

Online publication: September 12, 2024

1. Introduction

Climate change, driven by human activities, especially high carbon emissions, poses a major threat. The building sector accounts for over 40% of global energy use and 33% of greenhouse gas emissions, necessitating action [1]. Smart technologies, like IoT, integrated into building design, construction, and operation, can mitigate the carbon footprint and foster a greener economy.

Recent innovations in smart technology and advances in IoT-enabled devices have contributed significantly to the development of smart buildings. These devices are designed to collect critical data on energy consumption, lighting, temperature, and other environmental factors, enabling the optimization of energy use while reducing waste. Given these affordable IoT platforms, a variety of smart building solutions have been developed for a range of purposes such as occupant number and activity detection, health care in smart homes, and many energy-related applications and services [2–4].

From the existing literature and research, most scholars either explore from the perspective of how various links of smart cities cooperate to promote sustainability at the macro level, or from the perspective of how smart buildings can promote the sustainability of building construction, operation, or a certain component through the IoT at the micro level. This paper focuses on

how these independent building units can be connected to smart systems through IoT technology to contribute to sustainable cities and offers Chinese solutions.

In the next section, we will have a review on the state of the global building and construction industry as well as energy use and carbon emissions. Moreover, we will present the existing literature and cases on the application of the IoT in smart buildings for sustainability. Then, we will throw light on the evolution of smart buildings in China, especially under the participation of IoT. Followed by the focus on three typical cases of Chinese solutions. Lastly, we will summarize and give some suggestions about how IoT helps the building industry to develop a greener and more sustainable way.

2. Literature review

Buildings are one of the basic but crucial units for a human's living environment [5]. It is widely accepted that the use of new technologies is a fundamental prerequisite to achieve the realization of smart buildings, which includes but is not limited to, sensor deployment, big data engineering and analytics, cloud and fog computing, software engineering development, and human-computer interaction algorithms, etc. Among these supporting technologies, one of the trending areas is the development of IoT, as one of the challenges of smart buildings is to deal with a complex web of interconnected functional entities in different aspects of a building [6]. With the use of IoT, there is an enormous potential to make considerable progress towards more sustainable and climate-neutral economies as well as greener economies.

The concept of IoT refers to making every single "network-enabled" object in the world, representing a vision where the Internet extends into the real world by encompassing everyday objects [7]. Therefore, the basic idea of IoT is that everything around us can be connected, sense, and cooperatively communicate over the Internet. The application areas of IoT are various and based on current available technological solutions, the most represented application sectors are Smart Mobility, Smart Grid, Smart Homes/Buildings, Public Safety and Environment Monitoring, Medical and Healthcare, Industrial Processing, Agriculture and Breeding, and Independent Living. In recent years, these applications' existence and usability have attained a visionary scale and have become of paramount importance [8].

Recent technological progress in the field of IoT technologies has enabled smart buildings to monitor actual energy needs, optimizing consumption and therefore counting not only on green energy but also on a high degree of energy efficiency. The virtuous process that passes from smart energy allows us to count on Nearly (Net) Zero Energy Building (NZEB) and wider energy sustainability [9]. Moreover, the most common application of the IoT in terms of sustainability is home automation systems that manage energy consumption through connected devices to create an Energy Management System (EMS) for the home. For example, Viswanath developed a system with IoT element deployment and software design on residential buildings, which allows demand response adjustments to the building system to avoid peak or high price periods and achieve more balanced load control [10]. Smart energy solutions like these help consumers save resources, while energy and service companies can better balance production to meet actual demands. As the main effect, the energy consumption of families is reduced, also decreasing our impact on climate change [11].

Thanks to IoT and other smart technologies, not only individual buildings but also entire communities can be controlled remotely from an energy point of view. Several successful examples of smart communities exist worldwide. In Copenhagen, the "Smart Aarhus" project is a collaboration between the city government and private companies to develop smart solutions, such as smart lighting and waste management systems in public spaces. This project aims to reduce energy consumption and costs while boosting livability [12].

From smart buildings to smart communities and eventually grow into smart cities. IoT-enabled smart buildings serve as a stepping stone to a smarter, greener, and more sustainable city. By integrating renewable energy, intelligent transportation systems, and more efficient waste management, smart cities can optimize energy usage and promote green and sustainable living.

3. Major policy discussion

Generally speaking, in the context of booming digital

technologies and low-carbon economic transition, the Chinese government has formulated a series of policies. These policies aim to decrease consumption and dependence on fossil energy and reduce greenhouse gas emissions in the process of economic development through technological innovation, industrial transformation, and new energy development, to achieve a win-win situation between economic development and environmental protection, which have been further deepened with the introduction of carbon peaking and carbon neutrality targets.

With the rapid development of smart technologies like IoT, these policies are of great significance in exploring how digital technologies can help achieve the "dual carbon" goals, and smart buildings under the IoT system will inevitably become the future development direction of the construction and building industry. Since smart buildings involve many related fields, currently many construction enterprises are actively cooperating with various technology companies. However, only a few have the strength and China's smart building market is still in the early and transitional stage. Therefore, the depth and breadth of development need to be strengthened.

The sustainable development of city needs the participation of smart buildings. The smart management system and data analysis platform enable buildings to better adapt to environmental changes, improve resource utilization efficiency, and reduce operating costs. A study showed that the adoption of smart home systems in urban residential buildings can lead to a 14% reduction in energy consumption and thus contribute to reducing carbon emissions. In turn, the popularization of smart buildings can also promote the establishment of smart cities, which can further enhance the efficient use of resources, the reduction of emissions, and the improvement of urban

Table 1. Policy evolution of IoT-driven smart buildings in China

Time	Policy	Authority	Implications
March 2011	Outline of the 12th 5-Year Plan for National Economic and Social Development	State Council	For the first time, guidelines for building smart cities were introduced.
November 2012	Interim Measures for the Management of National-Smart City Pilots	Ministry of Housing & Urban-Rural Development	China's 1st batch of smart city pilot cities ordered.
March 2014	National New Urbanization Plan (2014–2020)	State Council	For the first time, the construction of smart cities was included in the framework of the national new urbanization plan.
November 2020	Recommendations on the preparation of the 14th 5-year plan for National Economic and Social progress and the Vision for 2035	State Council	For a start, the "dual-carbon" objective was put forward in the form of a document, emphasizing the consolidation of IoT sensing devices into the unified plan and building of public infrastructures, and the promotion of IoT usage and the smartness transformation in buildings.
April 2022	General Specification for Building Energy Efficiency and Renewable Energy Utilization	Ministry of Housing & Urban-Rural Development	The first mandatory carbon emissions target for the construction industry.
June 2022	Circular on the Peak Carbon Implementation Scheme for the Urban and Rural Construction Sector	Ministry of Housing & Urban-Rural Development，People's Republic of China (PRC) National Development & Reform Commission	Propose building green low-carbon cities, creating green low-carbon counties and villages, and peaking carbon emissions from urban and rural construction by 2030.
October 2022	Announcement of Pilot Cities for Smart Construction	Ministry of Housing & Urban-Rural Development	Beijing and 24 other cities are listed as pilot cities for smart construction for three years.

Source: Central Government website, https://www.gov.cn

environmental quality [13]. In general, aiming at realizing carbon neutrality, the Chinese government has formulated a series of policies to accelerate smart technology development, expand the smart building industry, and promote low-carbon development and sustainable urbanization.

4. Case study

The research method of case study is based on an in-depth investigation of the phenomenon and situation of individual cases, which is a comprehensive research method for specific problems [14]. In the following research process, we will discuss typical cases of the application of IoT to smart buildings in China and give suggestions on how IoT-enabled smart buildings help accelerate and navigate the shift towards a more environmentally friendly and sustainable development.

4.1. Winter Olympics Games program

The Beijing 2022 Olympic and Paralympic Winter Games adhere to the "green hosting" idea, utilizing low-carbon technologies and existing venues and facilities to the fullest extent [15]. Simultaneously, those newly constructed low-carbon venues, all adhering to green building criteria, include four ice venues that use new carbon dioxide (CO_2) refrigerants, and the completion of more than 50,000 m^2 hyper-low energy pilot projects. All venues utilize low-carbon energy, and 100% green electricity is used for conventional energy during the games to achieve carbon neutrality [16].

Artificial Intelligence of Things (AIoT) integrates Artificial Intelligence (AI), IoT, big data, blockchain, semiconductors, secure networking, and 5G. The Bird's Nest, leveraging AIoT, became the world's first 5G + AI + IoT cultural-sports venue. This fusion empowers IoT, enabling smart building upgrades. It optimized energy use with a distributed low-carbon network, transforming equipment and installing IoT nodes. The command center monitors energy in real-time, ensuring efficient utilization and reducing consumption by 20% to 30%. For health, Bird's Nest implemented a multi-dimensional system with more than 450 sensors and more than 2,800 control terminals for air quality, thermal comfort, lighting, etc., ensuring comprehensive environmental management.

According to the Beijing Olympic and Paralympic Winter Games Economic Legacy Report (2022), the smart building integrated system will serve the use of the Beijing Winter Olympics during and after the games, and become a demonstration project of Beijing's digital twin city in public buildings and residential communities. The Winter Olympics project will effectively solve the industry's pain point problem of emphasizing construction over operation, explore a new model of smart building design, construction, and sustainable operation in the post-Olympic era, and provide a demonstration case of "smart transformation and upgrading" for sustainable operation.

4.2. Haier Smart Home

Currently, China's traditional household appliances, mobile phones, digital products, household goods, and other industries have already been in a state of demand saturation, and the growth is weak. The emergence of smart homes will undoubtedly bring new development opportunities to these industries, especially since the current domestic smart industry of the whole house is still in its infancy, the market penetration is still relatively low, and consumers generally do not know enough about it. Compared with the fierce competition in traditional household appliances, mobile phones, digital products, household products, and other industries, the smart home market—particularly the whole-house intelligence sector—can be considered a blue ocean market with significant development potential.

One of the gravest concerns the current industry faces is the absence of system-level scene linkage and spatial interaction between smart home products, and the ecological interoperability and product incompatibility between various manufacturers. In 2020, domestic smart home enterprises exceeded 242,000 but the vast majority of them are smart single-product enterprises whose main business is smart appliances, smart locks, smart video, and audio. It can be seen that there are many smart home products on the market, but it is difficult for enterprises to integrate smart solutions for the whole house, and it is difficult to achieve connectivity and function integration in a true sense.

Haier Smart Home UhomeOS 3.0 is the latest upgraded version of the Haier Smart Home ecosystem,

based on IoT, cloud computing, big data, AI, and other technologies. Using behavior analysis, data analysis, data modeling, and other ways to achieve the goal of intelligence, connectivity, collaboration, and openness, to become the first enterprise in the industry to enter the decision-making intelligence. Different from the common hardware ecology and platform ecology which mainly focus on connected products in the industry, UhomeOS 3.0 is a complete and open smart home ecosystem. Through the interconnection between Haier itself and several manufacturers, it connects nearly 10,000 high-quality resource parties in various fields such as clothing, food, and decoration, and builds the largest smart home scene ecology in the industry, which realizes equipment interconnection, data sharing, and ecological collaboration.

For example, UhomeOS 3.0 supports a variety of manufacturers through ecological cooperation, covering a wide range of future household appliances. This includes features such as rapid preheating in intelligent ovens, negative ion adsorption in intelligent range hoods, and one-touch air purification in intelligent air conditioners. By leveraging data analysis and control, UhomeOS 3.0 manages and adjusts equipment based on user habits and provides tailored services.

4.3. Xiongan New Area

The establishment of Xiongan New Area in Hebei Province was issued by the Communist Party of China (CPC) Central Committee and the State Council on April 1, 2017. As a national plan for the millennium, Xiongan New Area is a new smart city. Xiongan New Area Smart IoT integrated transportation management platform with Building Information Model (BIM) as the carrier, uses IoT platform equipped with SiREID Engine, integrates the scattered equipment parameters and operation data of multi-brands and multi-systems into the daily operation and maintenance management functions of buildings and parks, and realizes the “strong combination” of BIM and IoT technology.

The development of city perception systems and IoT, combined with 5G, integrated networks, edge computing, and blockchain, has revolutionized traditional BIM model construction. AI enables models to learn from real-time data, generating new models through continuous adjustment. The Geographic Information System (GIS) + BIM + IoT model is widely discussed, focusing on loosely coupled data organization and model construction for various business scenarios, forming the City Information Modeling (CIM) mode, an initial state of digital twin cities, supporting future smart city operations [17].

The Xiongan BIM platform project records the real-time growth of Xiongan using digital technology and explores digital twin cities. It includes six stages: status quo, general regulation, control regulation, design, construction, and completion. Post-completion, the BIM model integrates with IoT for monitoring, early warning, and evaluation. Using XDB open data format, it combines big scene 3DGIS data, small scene BIM data, and micro IoT data, integrating municipal, civil, roads, landscaping, and urban furniture for comprehensive urban decision-making and governance [18].

Therefore, the Xiongan BIM management platform, as a platform integrating a variety of smart building technologies, can realize the whole-life cycle management and data-based operation of urban buildings, and explore the replicable and effective roads of transition from “individual smart” to “regional smart” and eventually to “urban smart.”

5. Conclusion

This paper briefly discusses how IoT and other smart technologies enable buildings to reduce carbon emissions and save energy, thus leading cities towards a greener and more sustainable direction, and ultimately achieving the goal of carbon peak and carbon neutrality. Based on the above research, we summarize the following suggestions for the future development of China’s smart building industry:

(1) To realize low-carbon construction and operation of buildings, a complete energy management system should be established with the help of IoT, carbon emission control and energy utilization optimization should be emphasized.

(2) A smart home is a smart building component unit. It is necessary to strengthen the interconnection and function integration between smart home products to realize the real sense of a home

automation system.

(3) Architecture is the "micro-unit" of the city. It is necessary to break the separation between smart buildings and smart city construction and promote the real-time linkage between the architectural brain and the urban brain. Greater energy efficiency and reduced environmental pollution can be achieved by connecting smart buildings to urban infrastructure.

This paper focuses on the status of China's smart buildings, without making a horizontal comparison with other countries in the world, to draw a more representative conclusion. Furthermore, smart technologies are being iterated and updated rapidly and China's smart building markets have strong potential for growth, the given suggestions won't stay the same all the time. We should always keep on researching to attain more sensible and sustainable results.

Disclosure statement

The author declares no conflict of interest.

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