# Integrating IoT Technologies for Smart Office Energy Management: A TOGAF® ADM-Guided Approach

Zitong Wang*
University of Melbourne
wangzt0330@gmail.com

Yuhao Zhao*
University of Melbourne
eddychao626@gmail.com

Yijie Long*
University of Melbourne
vanessalyj45@gmail.com

Xueyan Shi*
University of Melbourne
shixueyan0115@gmail.com

Xiyun Chen*
University of Melbourne
lucccy2r@gmail.com

Rod Dilnutt
University of Melbourne
rpd@unimelb.edu.au

## *Abstract*

*In an era of rapid technological development, companies attach greater importance to energy conservation and sustainable practices. Integrating Internet of Things (IoT) technology into the office environment, conceptualised as a "smart office," offers a promising path to improving energy efficiency. This study explores the application of the Open Group Architecture Framework (TOGAF®[1]) Architecture Development Method (ADM) as a strategic guide for implementing IoT in smart offices to achieve energy savings. By analysing the three phases of TOGAF ADM: business architecture, information system architecture (including data architecture, application architecture), and technology architecture, a system framework can be developed to bridge the research gap in enterprises' energy-saving solutions. This paper hypothesises that a structured application of TOGAF ADM will simplify IoT integration, optimise energy consumption and adhere to sustainability goals without compromising operational efficiency. This study is theoretical, based on a literature review, and focuses on enterprises that have implemented or plan to implement smart office solutions.*

## 1. Introduction

Today, an increasing number of enterprises have started to show interest in the concept of energy efficiency and sustainability. As a result, utilising new technologies to enhance enterprise energy saving becomes an important research topic. The enterprise office will often incorporate many systems, including lighting systems, HVAC systems, and various office equipment, and is being considered as a significant energy consumer. The concept of a smart office therefore emerges from smart cities, applying automation systems to office scenarios and is considered as being able to improve energy efficiency (Salosin et al., 2020).

The Internet of Things (IoT), as a technological revolution that has grown rapidly in recent years, is allowing virtual connections between the internet and physical devices. It is being considered as the key to smart city implementation, and smart offices are also relying on the integration of IoT technologies (Ryu et al., 2015). However, the IoT integration process may often face various challenges related to compatibility, scalability, and security, etc., and therefore may demand a solid architectural approach to act as a guide.

The TOGAF Architecture Development Method (ADM) is a framework that provides flexible and comprehensive guidance for the enterprises and ensures or facilitates the enterprise IT and strategic goal alignment. It was hypothesised that the use of the TOGAF ADM will provide effective guidance for IoT integration in smart offices, and help enterprises achieve higher alignment in their energy efficiency goal. We will explore the significance of different phases in the TOGAF ADM for their guidance in IoT integration by reviewing and analysing previous literature.

Among the past studies, a gap was observed that the integration of IoT in smart offices has not often been considered as a guided, systematic framework to improve energy saving. This paper will be aiming to focus on this gap and explore potential energy efficiency solutions in this sector through the implementation of the TOGAF ADM as a guide.

[1] TOGAF is a registered trademark of The Open Group

Therefore, we will be focusing on the following question in this paper: How to utilise the TOGAF Architecture Development Method (ADM) to guide the integration of IOT to achieve energy savings for enterprises implementing smart offices?

The scope of this paper will be limited to only consider the enterprises that have implemented smart offices, while not considering other possible influencing factors, such as the geographical and industry background of the enterprise. In addition, this paper will be mainly based on the analysis of theoretical frameworks and past literature, instead of getting evidence from actual project implementations. Therefore, the conclusions may need to be further adapted in future practical applications.

## 2. Literature review

### 2.1. Energy (cost) Saving

One of the main practices of using IoT technology to build smart offices, is focused on energy saving capabilities. By integrating the technology, companies will be able to reduce energy consumption through adjusting on its ventilation, air conditioning and lighting systems (Metallidou, Psannis and Egyptiadou, 2020).

By implementing sensors and controlling equipment, smart lighting systems based on IoT technologies could adjust the workplace lighting based on the weather, location, and the people density (Zheng, Qu, and Yu, 2019). Research from Lee, Chen, Chu and Hsieh (2022) shows that companies that adopt the IoT based lighting system could assist the company to reduce around 30% of electricity consumption.

The other practice of using IoT to build smart offices is using the technology to set up a smart temperature monitoring and control system in the office area. Based on studies of Vishwabath, Chandan, and Saurav (2019) as well as studies from Zhao, Peffer and Narayanamurthy (2016), companies using IoT capable air conditioning systems could save 10% to 30% of its energy usage compared to companies who does not use such kinds of technology in their workplace. During peak hours, IoT air conditioning systems could even save up to 60% of electricity consumption (Zhao, Peffer and Narayanamurthy, 2016). The reduction on the energy consumption could result in a decrease in carbon emissions and operational cost. It is also a show of corporate social responsibility and a support of sustainable development.

### 2.2. Internet of Things (IoT) Architecture

The term "Internet of Things" (IoT) was coined by Kevin Ashton, co-founder of MIT's Automatic Identification Center in 1999 (Tripathy & Anuradha, 2017). Since then, IoT has not only become the latest and most popular concept, but also evolved significantly, becoming a key technology in various fields (Touqeer et. al., 2021). IoT refers to a vast, interconnected network of smart devices with the ability to self-organise, exchange information, and pool resources. These devices are capable of autonomously responding to various scenarios and changes in the surrounding environment. (Rust, Picard, & Ramparany, 2022).

In other words, IoT facilitates communication between smart devices and between these devices and other Internet-connected entities, such as smartphones and gateways. This creates a broad network of connected devices capable of sharing information and independently performing various tasks (IBM, n.d.).

IoT technology and its architecture have been successfully practised in many fields and provides new services to citizens, companies, and governments. For example, in smallholder agriculture, IoT digital tools and services help monitor plants and environmental conditions (Antony et al., 2020). In addition, IoT technology is commonly used in building smart cities, such as home automation, smart energy management, traffic management, and automation of public buildings (such as schools, offices, and museums) (Zanella et al, 2014).

IoT architecture is mainly used to analyse advantages and challenges brought by IoT technology, and it typically consists of 4 layers from bottom to top (figure 1) (Toman et al, 2024). This hierarchical structure ensures that raw data collected from the environment is effectively processed and utilised to provide meaningful and actionable insights that enhance the functionality and efficiency of IoT (Herrero, 2023).

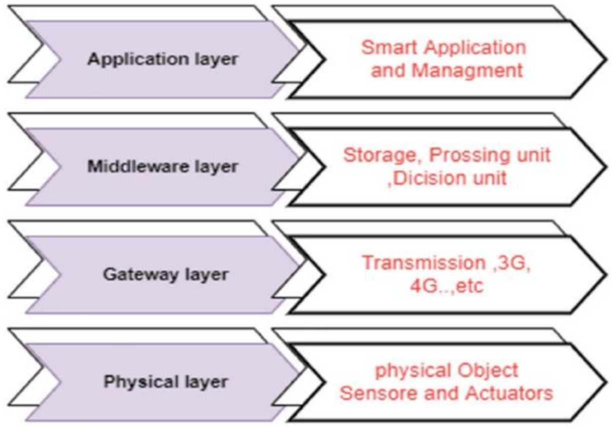


Figure 1: IoT Architecture (Toman et al, 2024)

**Physical Layer**

This is the base layer of the IoT architecture, where physical soft sensors are placed to collect data. These sensors detect and measure changes in the environment, such as temperature, motion, humidity, light, etc. In an intelligent system, this layer acts as a data source that will be processed and analysed.

**Gateway Layer**

This layer is responsible for combining and passing the information collected by the sensors to other parts of the IoT system for processing. The gateway acts as a bridge between the sensor layer and the network, converting and routing the data in the various protocols used by the sensor into a common protocol used by the network.

**Middleware Layer**

This layer acts as the interface between the gateway network layer and the application layer and plays a bidirectional role. It includes software and services that store, analyse, and process data to make it useful, such as data sorting, decision algorithms, and other analytical capabilities, such as cloud computing platforms.

**Application Layer**

This layer is at the top of the IoT architecture. At this layer, the processed data is ultimately used to execute specific applications that benefit the user, including the user interface and application software that provides IoT services to the user.

## 2.3. Smart Office

Smart cities represent a complex ecosystem encompassing various aspects such as transportation, energy, and public infrastructure (Lee, 2020). As illustrated in Figure 2, the infrastructure of a smart city includes diverse business architectures from factories and office spaces to data centres (Mohanty et al., 2016). This multi-layered integration underscores the crucial role of smart offices not merely as an extension of technology but as a core component of urban infrastructure. Smart offices utilise IoT technology to automate and optimise resource management, aiming to enhance the work environment. This integration not only enhances employee productivity and energy efficiency but also significantly reduces operational costs. (Papagiannidis & Marikyan, 2020).

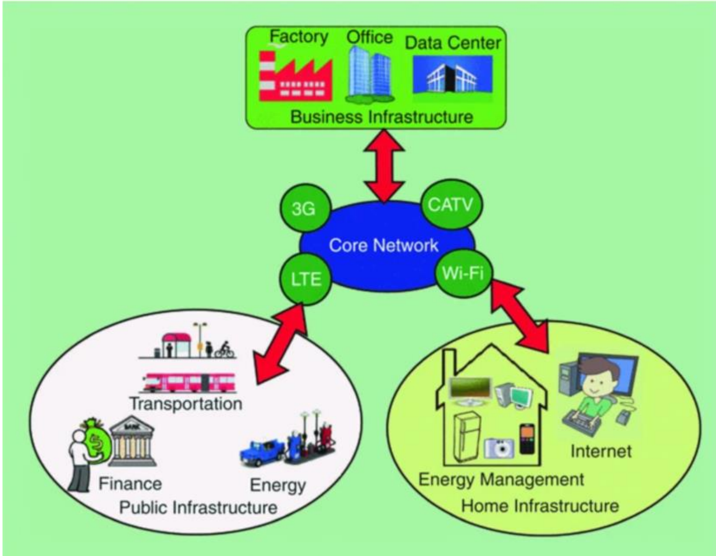


Figure 2 smart city infrastructure depictions. (Mohanty et al., 2016)

### 2.4. IoT Application in Smart Offices

Smart offices transform everyday office environments into highly automated and interconnected workspaces by integrating Internet of Things (IoT) technology (Prasetyo et al., 2018). This technology enables devices to connect and communicate with each other, thereby enhancing work efficiency and improving the overall functionality of the office.

The IoT architecture in smart offices typically consists of the following four layers:

**1. Sensor Layer**: In smart offices, the sensor layer plays a critical role in collecting real-time environmental and behavioural data. This data ensures that office systems can respond adaptively to changes, enhancing comfort and efficiency. For instance, sensors adjust lighting and climate controls automatically as a meeting approach, aligning with users' preferences (Olivieri et al., 2015). However, there is room for improvement as sensors may not always accurately detect occupancy, leading to potential energy wastage (Shen et al., 2017).

**2. Gateway and Network Layer:** According to Stojanoski et al. (2017), these layers facilitate data transmission from internal devices, such as environmental monitoring microcontrollers, to client interfaces like smartphone apps, using a range of wireless communication protocols including Bluetooth LE, ZigBee, RFID, NFC, Wi-Fi, and LTE. While gateways effectively collect and standardise data from different sensors for network processing, the diversity of these protocols can introduce significant integration challenges. As Chan & Shum (2018) and Minoli et al. (2017) highlight, inconsistencies among device and system protocols can complicate real-time data processing and impair energy efficiency optimization, leading to potential delays and reduced operational efficiency in smart office environments.

**3. Management Service Layer**: In the SoPIoT platform, each device must register its abstract model through a uniform interface mechanism. This model includes the device identifier, the values it provides, and its service functions. This layer of abstraction does more than just conceal the hardware specifics—it facilitates the seamless integration of third-party devices that were initially developed for different IoT platforms (Lee et al., 2017). However, this integration poses significant challenges. The diverse systems and their differing protocols can lead to complexities in the effective management and optimization of energy usage. These complexities can introduce potential inefficiencies within the smart office's IoT infrastructure, particularly when it comes to energy management (Ali et al., 2021).

**4. Application Layer:** This layer's core function is to convert data collected from lower layers into practical applications, thereby improving work efficiency and comfort, while ensuring smooth implementation of office automation. The application layer offers various smart services, such as intelligent meeting management: an automated meeting room booking and management system that can adjust room facilities according to the meeting schedule, including preparation of video equipment and presentation tools (Olivieri et al., 2015). However, a significant challenge remains in balancing energy efficiency with occupant comfort. Often, efforts to optimise energy use in smart offices can compromise comfort levels, leading to dissatisfaction and reduced productivity (Liu et al., 2023).

## 2.5. TOGAF ADM

Qurratuaini (2018) explains TOGAF as an enterprise architecture framework, and it is commonly used to develop enterprise performance from a comprehensive perspective integrated with businesses' strategic directions, business practices, information flows, and technology resources. The TOGAF Architecture Development Method (ADM) is the core part of the TOGAF framework and is an iterative process for the development of enterprise architectures (Qurratuaini, 2018). Specifically, it can be divided into the preliminary phase, architecture vision, business architecture, information systems architecture, technology architecture, opportunities and solutions, migration planning, implementation governance, and architecture change management as shown in Figure 3 (Qurratuaini, 2018).

Among them, Handoko (2018) emphasises the following four architectures domains are of great significance and could have an effect in producing the architecture requirement and architecture roadmap. Business architecture is related to describing the current organisational architecture and can be used to formulate strategic solutions to achieve future business goals. It is the foundation of the other three architecture domains (Hermawan & Sumitra, 2019). Information systems architectures include two aspects that are data architecture and application architecture (Hermawan & Sumitra, 2019). To be specific, data architecture refers to data entities used in business functions, the relationships between entities, and the organisation and access of those data in enterprises, while application architecture is relevant to the design and interactions between specific applications (Betz, 2011). Finally, Betz (2011) mentions technology architecture as the software and hardware components needed to support the delivery of information systems. Similarly, common steps of those three architectures include defining baseline architectures and principles, designing target architectures, conducting gap analysis, devising roadmaps, and implementing migration plans (Qurratuaini, 2018).

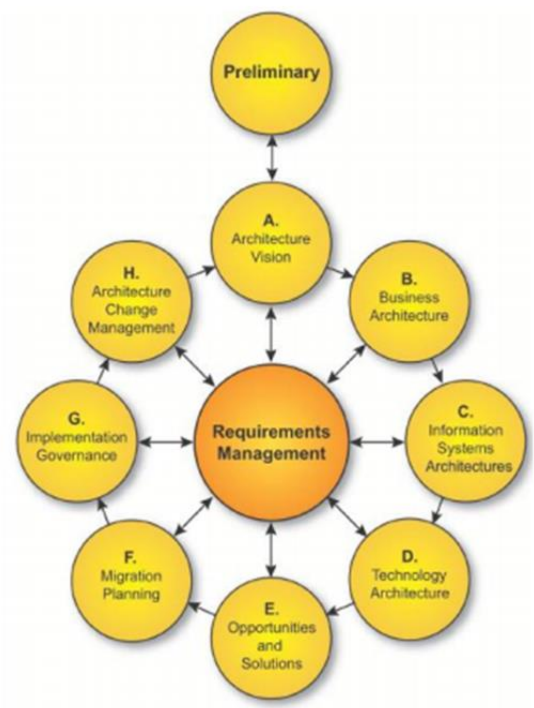


Figure 3: TOGAF ADM iteration and phases (Qurratuaini, 2018)

Compared with other enterprise architecture frameworks like the Zachman Framework ™[2], DoDAF, and Gartner, Qurratuaini (2018) mentions the benefits of the TOGAF framework in terms of the completeness of processes, flexibility, integration between different layers, and standards.

According to Alm and Wißotzki (2013), the flexibility of the TOGAF framework could be reflected in the customization of the framework like simplifying or skipping some steps and minimising documentation in the ADM based on the nature and objectives of individual companies.

Actually, the TOGAF framework is commonly used in the enterprise architecture development of smart cities through understanding cities as complex enterprises (Bastidas, Bezbradica & Helfert, 2017). To be specific, through applying the TOGAF framework in designing smart city architectures, those elements are identified including goal and business processes in the perspective of business architecture, data entities used from the view of data architecture, application portfolio and interface catalogue, and technology standards like cloud computing, big data, IoT and related smart city techniques (Bastidas, Bezbradica & Helfert, 2017).

As a component of a smart city, smart offices could be developed using the TOGAF framework, and there are some successful cases. For example, Muhammad Azhari et al. (2023) simply mentions a case of smart meeting rooms based on the TOGAF framework, which determines and designs the enterprise architecture of these smart meeting rooms and ensures the alignment between IT solutions and business objectives.

## 3. Discussion

### 3.1. Research gap

Through reviewing past studies, it was found that although many of them have been exploring the relationship between IoT integrated smart office implementation and energy saving, they were mostly focusing on the technology adoption itself, without giving much consideration over how potential systematic framework guidance could impact the process and organisational strategic goal fulfilment. In addition, there are also previous studies that focused on the application of the TOGAF ADM framework in smart city, yet, not having targeted research in IoT based smart office energy saving.

Therefore, this study is aiming to fill this research gap by integrating the concepts of the TOGAF ADM, IoT-based smart office and enterprise energy saving strategic goals, and propose the adoption of the TOGAF ADM, which could provide flexible and comprehensive guidance for the enterprises, to manage the integration of IoT in the large energy consumers - smart offices. We will discuss and analyse this potential approach and formulate hypotheses based on the current research literature reviews.

### 3.2. Hypothesis

#### 3.2.1. Business architecture

At the business architecture stage of the TOGAF ADM, the first step is to comprehensively map the existing business processes in the smart office. This mapping focuses on all activities and processes directly related to energy consumption, such as HVAC management, lighting control, and equipment operation. The results of this mapping will reveal which processes are the main sources of energy consumption and where there are gaps or inefficiencies in energy management.

Building upon this foundation, developing, or reshaping business processes to integrate new functionalities, particularly energy monitoring and analysis, is a key strategy. These functionalities must not only be deployed but also effectively support the business needs for energy management. For example, a process could be designed to embed energy monitoring and analysis into daily business activities, ensuring that energy usage data is collected and analysed daily to monitor and optimise energy consumption. Additionally, regular reviews of energy usage, such as weekly and quarterly checks, can identify opportunities for savings and assess the effectiveness of implemented energy-saving measures. An annual energy management report would compile a year’s worth of energy usage data and savings outcomes, evaluate how these align with set targets, and provide data support for the next year's energy management strategy.

[2] Zachman Framework is a registered trademark of Zachman International.

### 3.2.2. Information System Architecture

**Data Architecture**

In the information systems architecture phase, both data architectures and application architectures need to be considered. For data architectures, types and sources of data need to be defined to support the organisations in a way that can be easily understood by the stakeholders.

In the context of smart offices, core data entities including sensor data, user interaction data, and device data are of great importance (Furdik et al., 2013). To be specific, environment data are collected from sensors to support the function of energy monitoring and saving (Furdik et al., 2013). According to Degeler et al. (2013), temperature, light sensitivity, and humidity are common considerations in the target data architecture of the smart office system. Besides, user action data entities like employee working time that could be acquired through RFID readers could be designed in the target data architecture (Furdik et al., 2013). Furthermore, air conditioning system data, utilisation data of office equipment like printers or laptops and lighting device status need to be considered (Degeler et al., 2013). Attributes and relationships of those data entities need to be clarified in the data architecture. By combining those various types of data, the smart office could assist enterprises to achieve energy efficiency.

Besides, data management strategies including the storage and integration of different sources of data should be clarified in the data architecture. Furdik et al. (2013) propose a feasible method of integrating sensor data and device data through a middleware to provide a unified data access interface. Moreover, data could be stored through key-value stores or NoSQL databases to achieve quick access and processing of data to meet real-time monitoring and analysis (Mehta et al., 2021). Moreover, data encryption and access control methods could be applied to ensure the security of data in storage and transmission (Furdik et al., 2013).

**Application Architecture**

In the application architecture phase, application components and the integration between them should be considered in the target application architecture in smart office systems. Specifically, some applications may be missing in the current application architecture. Thus, those applications will be added into the target application architecture to support organisations' business processes (Qurratuaini, 2018). For example, an intelligent lighting control application is commonly included in the smart office system to track, analyse, and optimise energy usage (Salosin et al., 2020). Specifically, Salosin et al. (2020) report that enterprises could use this feature to control the operation of lighting devices regardless of their locations and types, reducing energy costs by an average of 35%. Climate controlling application is also an indispensable part of the smart office system (Salosin et al., 2020).

Additionally, all applications need to be integrated in the target application architecture scheme (Qurratuaini, 2018). For instance, a unified user interface could be included in the target application architecture to manage all related applications to reduce complexity and enhance efficiency.

**Technology Architecture**

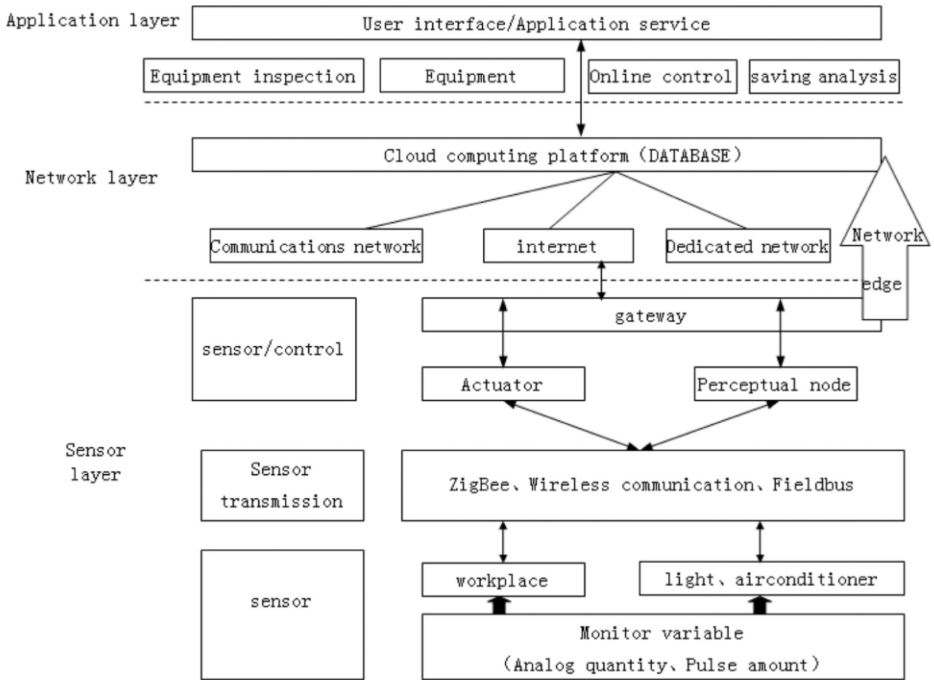


Figure 4: IoT architecture model of office building (Zheng, Qu and Yu, 2019)

Linking back to the two selected types of IoT-based smart office technologies, which are smart lighting and smart air conditioning systems, the technology architecture to construct the two systems could fall under the following four levels (Toman et al, 2024).

At the application level, both systems require an application service with a user interface for users to control the system. The software application also has functions to control all the lights and air conditioning based on the embedded sensors in the workplace (Zheng, Qu and Yu, 2019).

At the middleware level, the system will use the data collected from sensors to analyse the situation on the floor. Then the system will send out orders either based on manual or automated control, which will result in a change of brightness or temperature in the office (Lee, Chen, Chu, & Hsieh, 2022).

The system communicates information through the network embedded in the office. Through dedicated internet networks, the sensors, server, application, and other parts of the system are connected to control the lights, temperature, and humidity in the workplace. The system also utilises the Zigbee protocol to connect some of the IoT sensors with the controlling network (Zheng, Qu and Yu, 2019, Cvitić, et al., 2021).

At the sensor (physical) level, light, temperature, humidity, air quality, and human presence sensors will be the system's main sensors. These sensors will detect the situation around the working area and adjust the energy usage based on the situation of the designated area. Adopting these sensors will avoid wasting energy on unnecessary light and air conditioning usage, resulting in significant energy savings (Zhao, 2016, Zheng, Qu and Yu, 2019).

### 3.3. Implication & Significance, Future Research Directions

This study aims to achieve theoretical implication by filling the current research gap of TOGAF ADM guidance on IoT-based smart office energy management and raising new hypotheses through systematic integration among concepts. This would complement the theories of building more sustainable office environments, allowing companies or enterprises to conduct theory implementation more accurately in their references. This study would provide new perspectives and a new theoretical framework to guide smart office energy management and energy-saving implementation, therefore driving theoretical advancement in this domain of study.

From practical perspectives, based on the theoretical implication, this study provides enterprises with potentially feasible guidance and solutions to achieve their strategic goals on energy efficiency. Through implementation over the developed theoretical framework, they are enabled to monitor and manage energy consumption in smart offices more effectively. Major practical implications and significance of this research to enterprises would include guidance to achieve their sustainability objectives, enhancing their operational efficiency while reducing operational costs, and improving their Environmental, Social, and Governance (ESG) ratings (Escrig-Olmedo et al., 2019). On a larger scale, the implication of this research would extend to the global sustainability goals, including the reduction of carbon footprints.

In this study, we conducted a thorough literature review and formulated corresponding discussions and hypotheses. Yet, our analysis is limited to the theoretical framework and does not have empirical data to support the findings. Therefore, it is suggested that the future research directions can be oriented towards implementing data collection, as well as conducting long-term impact assessment over how the TOGAF ADM guidance influences IoT integration in smart offices and how it changes energy management for enterprises.

## 4. Conclusion

This study highlights the potential of TOGAF ADM to effectively guide the integration of IoT technologies in smart offices to achieve energy savings. By following TOGAF's structured approach, businesses can align IoT implementation with energy efficiency and sustainability goals to suit unique business needs. While the findings are theoretical, they highlight the need for further empirical research to validate and refine the real-world application of these strategies. Future research should focus on practical implementations to enhance the robustness of the method and help businesses achieve significant energy savings and operational efficiency.

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