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Key factors of adopting energy management systems in building sector in Taiwan

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ABSTRACT

It is no doubt the world is experiencing global warming and human emission causes distinct climate change. According to the analysis from International Energy Agency, the over consumed nature resources from power, industry, transport and building sectors are off the major factors reflecting on the essential greenhouse gases to life. As moving onto the smart technology and smart grid development, recent studies indicate that using the advanced energy management systems is critical to improve power efficiency, energy saving, and reduce greenhouse gas emission. This study relies on a systematic literature review and expert opinion to identify the critical factors of adoption building energy management system. Finally, a framework is presented to evaluate the introduction of energy management systems in the construction field in order to achieve zero carbon ready buildings.

Keywords: Zero carbon ready building, Nearly zero energy buildings, Building energy management Systems, BEMS, Energy Management Systems, TOE.

INTRODUCTION

Climate Change

In 2022 scientists observed a raising temperature upto 40 degrees centigrade in the United Kingdom, already 28 years ahead of scientific prediction. Additionally, the uncommon high temperature observed in Nordic area, especially in Sweden, for over one week. Nowadays the extreme abnormal weather causes the environment changes, for example heat waves, drought, tsunami, hurricanes, melting polar ice caps, icy coastal decline, forest fires, and raising sea level…etc of that driving grand attention to problems of global warming syndrome.

Most of scholars' researches revealed radiation release from atmosphere, and heat trapping gases over planet are conducive to greenhouse effect. Carbon dioxide has increased 25% out of origin since 1850 while human activities reacted on overheating fossil fuels, landfills burning, and deforestation. The key factors of greenhouse effect (CO2, methane, nitrous oxide, and CFC/HFC..etc) grew times above average level on earth. In between 2010 and 2019 we witnessed challenges on the severe problem of global warming effect, and percentage of CO2 ratio hit the highest record in 650,000 years (Berger & Tricot, 1992; Bouckaert et al., 2021; IEA, 2020; Raval & Ramanathan, 1989; Rodhe, 1990).

The Intergovernmental Panel on Climate Change (IPCC) reports that scientific studies on the impact of global warming reaches world record high since 1950, especially researches on climate changes of hydrosphere, cryosphere decline, severe raising sea level damaging biosphere safety. Solution for mitigating rampant climate change, or rather say "climate crisis" have been groundwork for catering for a resolution, replacing general concept on global warming effect (Houghton et al., 2001).

Net-Zero Emissions (NZE)

IPCC report on "Global Warming of 1.5 ºC" indicates that the speed of global warming transcends scientific prediction. It is of no doubt all member states shall limit carbon emission release in half before 2030, and the additional suggestion on global warming emission be strictly controlled less than 1.5 ºC, based on the benchmark of average global temperature in 1990s. Approaching this target on Net Zero emission be of the milestone before 2050, in order to tackle mundane impact and challenge on climate change (IPCC, 2018).

In May 2021, the International Energy Agency (IEA) report for mission on "2050 Net Zero Emission Roadmap" indicates among total 33.9Gt (Gigatons) of global Greenhouse Gas (GHG) of which 13.5Gt (share 39.7%) from Energy sector, 8.5Gt (share 25%) from Industries, 79Gt (share 21.2%) from Transport, 29Gt (share 8.5%) from building, and others for 19Gt (share 5.6%). Meanwhile fossil fuels occupy 80%, and consumption on coal mining, natural gas, and gasoline are increasing, exceeding 60% of total power distribution that de factor be of major impact on climate change (Bouckaert et al., 2021; IEA, 2020). Thus, framework for targeting on Net Zero Emission Roadmap narrows down on these four major sectors: power, energy, industry, transport, and building.

Furthermore, the IEA report on achieving Net-Zero Emissions codes all member states to comprehensively comply within thirty years: efficiently optimize power consumption, adjust humane behaviors, replace by renewable and sustainable energy, decline on fossil fuels, gas, and oil usage, deploy the available clean energy technologies, implementing energy control & monitoring system, purposely focus on limiting greenhouse emission.

Therefore, providing smart grid technology and smart building with diversified Energy Management System (EMS) be of the key solutions of that real-time data record demonstrates power utility, amending energy using behaviors, optimizing power consumption in order for reaching Net-Zero Emission, and upcoming GHG emission target.

Improving the efficiency of power consumption in building sector, and developing green and clean energy buildings drive attention to deploy high-tech solutions, the energy management system, smart meter, and micro grid, aiming to provide zero carbon ready buildings.

LITERATURE REVIEW

Energy Management System

Maghsoodlou et al. (2004) stated that the energy management system (EMS) is the core system of the power network system, and the EMS is the key facility for the power grid control center to maintain the power utility's reliable operation. EMS is one console mechanism that the tool monitors and manages power utility, the "Supervisory Control and Data Acquisition (SCADA)", efficiently generates power by concise analysis and computing, transmits and distributes power to end demand side in a greater production. The EMS aims to enhance operations of power utility, such as adjusting power stream, the upmost utility of power consumption, monitoring real-time power sub-stations, and efficiently transmitting and control operation safety. Especially, the advanced EMS system also grants higher computing power for optimization (Abhinav & Pal, 2018; Garrick, 2008; Tran et al., 2021).

Due to the rapid development of smart grid, micro grid, smart meters and IoT solutions, EMS has been deployed in variety of industrial scales, such as building energy management system (BEMS), factory energy management systems (FEMS), and home energy management system (HEMS).

By actively collecting data of power measurement on physical side, for example providing information referring to real-time power consumption, kernel for utilizing on networking resources, monitoring the abnormal events, and decision support, the facility manager easily operates whole power grid and demand facility. Buildings that integrate EMS achieve unattainable levels of energy savings after the EMS implementation. (Budka et al., 2016; Mahajan et al., 2021; Paul et al., 2014; Segatto & de Oliveira, 2018; Shrouf & Miragliotta, 2015; Shrouf et al., 2014; Yang et al., 2017).

According to prior researchers' examination, the advanced BEMS system enables well management on power utility, and the change for interior amenity. For example, auto-adjust interior lightning, interior ventilation, and humidity or temperature. More, comparing the stereotype concretes, BEMS embedded buildings reduce 30% of power consumption, achieving the innovation, smart and energy saving target with amicable amenity (Aarås et al., 2001; Desideri & Asdrubali, 2018; Fisk, 2000; Noye et al., 2016; Pérez-Lombard et al., 2008).

Zero carbon ready building

According to the IEA report, the building sector has large carbon footprint with about 9% CO2 emissions from using fossil fuel energy, 18% from electricity and heat used, and an additional 10% from the manufacturing of construction materials (IEA, 2021).

D'Agostino and Mazzarella (2019) studied the national energy policies by introducing technical regulatory measures to improve the energy efficiency of buildings and the generation of renewable energy sources (RES). Reducing the energy demand by using RES and using energy efficiently have achieved common agreement to the nearly zero energy buildings (NZEB) concept.

According to the International Energy Agency, "A zero-carbon-ready building is highly energy efficient and either uses renewable energy directly or uses an sustainable energy supply that will be fully decarbonised by 2050, such as electricity or district heat (Bouckaert et al., 2021)." Before reaching zero carbon ready buildings, IEA initiated "enhancing development and projects of nearly zero energy buildings" since 2019, and by 2021, it provides technical guidance for nearly zero energy buildings, including definition, energy criteria, technical performance index, technical measures, and evaluation.

To meet the Net Zero Emissions by 2050 Scenario, the energy intensity of the building sector must fall nearly five times faster over the next ten years than it did in the previous five years. This means that in 2030, the energy consumed per square meter must be 45% lower than that in 2020. Furthermore, the traditional use of solid biomass, which is extremely inefficient and has been linked to approximately 2.5 million premature deaths from household air pollution in 2020, should be phased out completely by 2030. By shifting to modern solid biomass, biogas, electricity, and liquefied petroleum gas (LPG), the Net Zero Emissions by 2050 Scenario achieves universal energy access by 2030 (IEA, 2021).

Another action conducive to achieve Net Zero Emissions by 2050 scenario is implementing mandatory zero-carbon-ready building codes for all new buildings by 20230. These standards should cover both operational and construction-phase energy intensity and emissions, in line with the most recent EU policy developments such as France's new RE2020 standard. The new buildings compliance with the zero-carbon-ready building code should include EV charging, demand management, help buildings to accommodate variable renewable energy sources and a net zero electricity system (IEA, 2021).

Substantially the investment and spending has increased, it is inherently challenging to have triple investment by 2030 to achieve the Net Zero Emissions by 2050 scenario's milestones of reaching deep energy retrofit rate of ~2.5% per year. IEA also suggest that all the new buildings need be Net Zero Emissions ready to meet the 2050 goal.

TOE framework

When researching organizational acceptance of technological innovation, Tornatzky et al. (1990) proposed the technological organizational environmental (TOE) framework and concluded that the influencing factors fell into three categories: organization, technology, and environment. It describes the entire innovation process, from innovation development by engineers and entrepreneurs to adoption and implementation of those innovations by users within the context of a firm. The TOE framework represents one aspect of this process, namely how the firm context influences innovation adoption and implementation.

Alshamaila et al. (2013) The TOE framework is an organizational-level theory that explains how innovations are adopted and implemented. These are three elements posited to influence firm technological innovation, and those discussed below.

Technology

The technological context of the firm represents its technological capability, both internal and external. Those technologies are already in use at the firm, and others are available on the market but are currently unutilized.

Organization

The organizational context is related to the resources, cultures, and characteristics of the firm such as executive board, professionals, firm size, managerial structure.

Environment

Environmental context refers to the environment where a company operates including elements cohering with regulation, supply chain, competitors, and industry alignment.

The TOE framework proposes that factors influencing innovative information system (IS) or technology adoption behavior can be broadly classified into three contexts: technological, organizational, and environmental. Many scholars have used the TOE framework to explore various innovative technology adoptions in many technology or industry territories, because it is a comprehensive organizational level research theory for investigating new technology intentions.

RESEARCH DESIGN

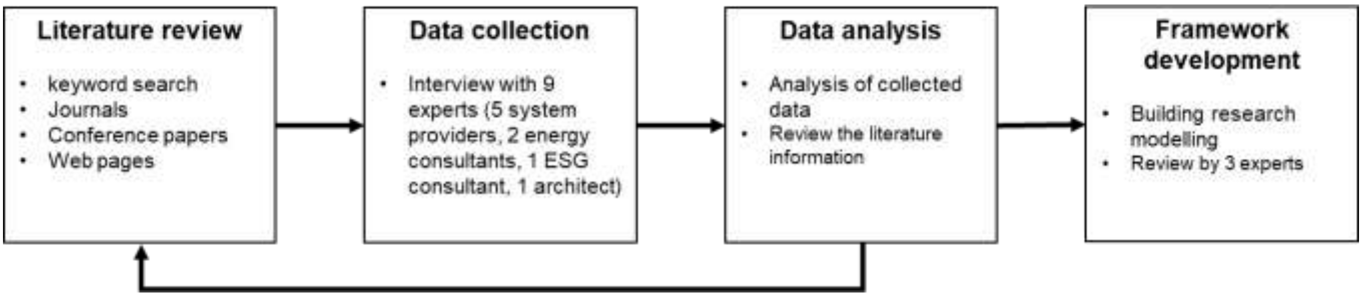
This research design is illustrated Figure 1.

First, approaching search engine (Google Scholar, ScienceDirect, and Elsevier) to select documents of literature review, analyzing theoretical frameworks referring to adopting building energy management system (BEMS), and the improvement of building energy efficiency. By doing so includes critical evaluation of BEMS definitions, technologies and smart building applications. For the purpose, several keywords are used in the search process, such as "energy management system," "building energy management system," "adopt energy management and TOE", "BEMS and TOE", "TOE and adopt information technology" and "TOE and adopt cloud applications".

Second, given the nature of this research paper purposely for a qualitative research approach, based on regular interviews through concept of data collection, ie. the interview on nine expertise. There are five executives of technology and solutions providers: two presidents, one engineering director, and two professional electric & electronic experts. Except the above five executive professionals we also include two consultants from energy sector, one V.P of ESG Consulting Group International, and one experienced architect.

Third, compare the prior Literature review reference with data collection interviews analyze similarities among materials, examine relativities, and root cause of research orientation, aiming at simulating and building up frame work models.

Last but not least, relying on the literature review and interviews, inducive modeling is adopted to build a framework for enterprise energy management system, so as to define how energy information is able to integrate into construction projects and property operation.

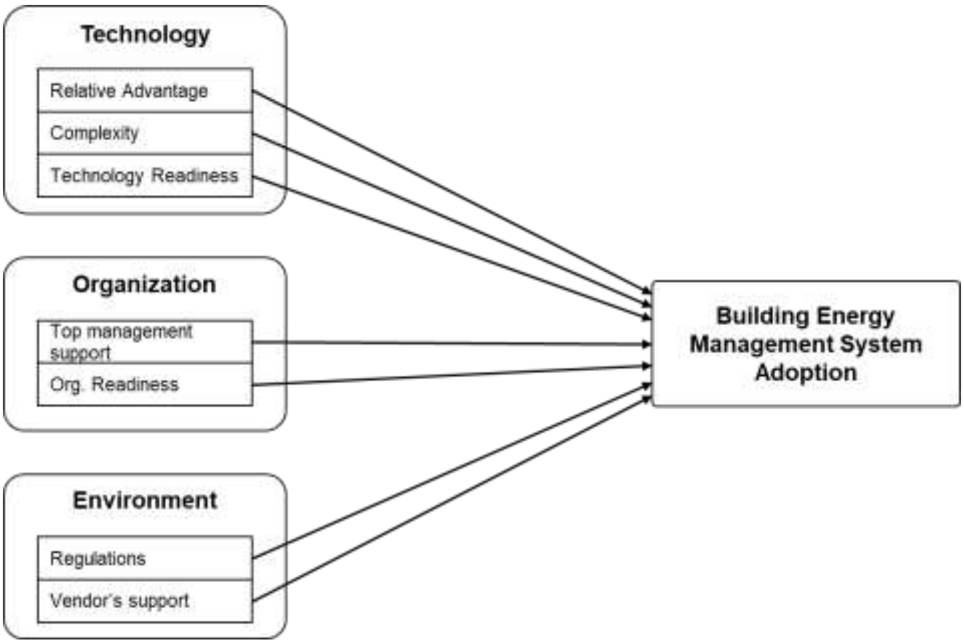


Source: This study.
Figure 1: The research design.

RESULTS DISCUSSIONS

By conducting a literature review to identify potential factors, driving those construction companies' adaptation for energy management system, this study then assesses the importance of those factors through interview with experts. In the end, the study proposes the analysis model to explain the key factors of companies to adopt BEMS referring to pervious modifying TOE framework (Gangwar et al., 2015; Hung et al., 2014; Premkumar & Roberts, 1999; Pumplun et al., 2019; Ramdani et al., 2009).

In order to make an in-depth analysis, this study targets those construct company and building operation' that adopts energy management system. As to the variables definition, all of the operational definitions and assessment are derived from the relevant literature. The operational definition of variables are summarized in Table 1, and the research model is illustrated in Figure 2.



Source: This study.
Figure 2: The framework from lecture.

Technology Context

Relative Advantage

Rogers et al. (2014) define relative advantage as " the degree to which a technological factor is perceived as providing greater benefit for firms". Premkumar and Roberts (1999) also study that with these technological factors, the adopters can enjoy the benefits which reduce turn-arround time, lower down the cost, provide highier customer service level, get timly information for making decisions. By Alshamaila et al. (2013), the relative advange on technology adoption has been widely accepted in all kinds of previous studies. In organizations, having an advanced technology which provide better benefits than other alternatives is a key consideration in adoption for the decisions. Bandara and Amarasena (2018) study found that relative advantage, perceived behavior control, and perceived ease of use are positive factors to influence the adoption of new solar technology.

Adopting new technology has a higher relative advantage than maintaining existing technologies. In the study of Premkumar and Roberts (1999) and Ramdani et al. (2009), it was considered that the idea of innovation is better than the idea of been replaced. The study found that the relative advantage is such a critical factor and it is positively related to the adoption of innovative technology. Before the organization taking a new technology, it requites reseasonable evaluation. When the organization perceives the new information system (IS) that provides relative advantage, it grants better opportunities to been adopted. Especially among highly competition industries, adopting to new technology which has relative advantage can benefits from increasing sales revenue, improving the process or lower down the operation and management cost. Those benefits become important driving factors pushing industries for adopting new technologies (Alshamaila et al., 2013; Gangwar et al., 2015; Lee, 2004; Markus & Tanis, 2000; Valdebenito & Quelopana, 2019).

This study intentionally summarizes those previous researched and defines the relative advantage as “the advantages and competitive abilities of company to enjoy after the adoption of a new energy management system compare to before the adoption. Such advantages and competitive potentials are aim to realize the zero carbon ready building”.

Table 1: The definition of Adopting building energy management system.

Context	**Factor**	**Description**	**References**
Technology	Relative Advantage	the advantages and competitive abilities of company to enjoy after adoption of a new energy management system compare to before the adoption. Such advantages and competitive potentials are aim to realize the zero carbon ready building.	Alshamaila et al. (2013); Bandara and Amarasena (2018); Gangwar et al.(2015); Lee (2004); Markus & Tanis (2000); Premkumar & Roberts (1999)
	Complexity	the degree of understanding new technology and the ability to fine-tune and improving the technology after adoption.	Beaudin and Zareipour (2015); Grover (1993); Parveen & Sulaiman (2008); Ramdani et al. (2009); Thong (1999)
	Technology Readiness	supporting companies’ eco demands which have the key driving factors including to build up green technology infrastructure and the IT process to support low carbon emission.	Molla et al. (2008); Mutula and Van Brakel (2006); Parasuraman (2000); Valdebenito and Quelopana (2019)
Organization	Top Management Support	the commitment and support from top management to adopt energy management system, which provide resource for the organization and belonged buildings to achieve energy-saving and eco-friendly goal.	Britel and Cherkaoui (2022); Gangwar et al. (2015); Jovanović & Filipović (2016); Salwani et al. (2009); Zhang et al. (2018)
	Organization Readiness	the capabilities and resources for companies to adopt energy management system which including training, financial readiness, organization culture and management process.	Britel and Cherkaoui (2022); Lokuge et al. (2019); Ramdani et al. (2009); Valdebenito and Quelopana (2019)
Environment	Regulations	government’s deadline to implement energy reduction and nearly zero energy buildings (NZEBs), and also the government incentives for building companies to adopt energy management system (EMS) or other innovation technology.	D'Agostino and Mazzarella (2019); IEA (2021); Pumplun et al. (2019); Salwani et al. (2009)
	Vendor’s support	the capabilities of a supplier to provide EMS and technology, deliver knowledge and supporting service.	Dedrick & West (2003); Gutierrez et al. (2015); Lal and Bharadwaj (2016); Maghsoodlou et al. (2004)

Source: This study.

Complexity

The complexity was defined as “the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters (Rogers et al., 2014).” Sonnenwald et al. (2001), “Complexity is defined as the perceived degree of difficulty on understanding and using a system.”

Premkumar and Roberts (1999) study found that complexity is the degree of difficulty associated with understanding and learning to transform into innovation immediately. The complexity of the innovated technology creates greater uncertainty for successful implementation, and therefore increases the risk in the adoption decision.

The complexity of innovated technology will increase the uncertainty of adopting a new technology. Some studies focus on the factor of decision risk of adoption of new technology and system. According to previous study, such decision risk factor is negative related to adopting a new information system. Similarly the decision risk is also an important factor for small enterprise’s adoption of new IS (Gangwar et al., 2015; Grover, 1993; Parveen & Sulaiman, 2008; Thong, 1999).

Beaudin and Zareipour (2015) addresses that each equipment has its own attributes, even some studies try to modeling the home energy system (HEMS) and simplify the operation process, it is still difficult to figure out an intuitive model to manage various equipment. Especially there are still kinds of external environmental limitation and different operating criteria and complexity. To improve setting up the management system is fairy necessary.

This study defines the "Complexity" as "the degree of understanding new technology and the ability to fine-tune and improving the technology after adoption."

Technology Readiness

Information technology (IT) has the potential to influence not only competitive capability, but also business development and even the parts of corporate strategic options. Most executive officers and IT managers are dealing with two competing demands: First, to establish a stable information infrastructure will support business processes smoothly; the other, to import cutting edge information system provides the most innovative business services.

Parasuraman (2000) defined technology readiness as "the propensity to embrace new technology for accomplishing goals is determined by the overall state of mind resulting from a gestalt of mental contributors and inhibitors." This study classifies organizations into five segments on the basis of accepting technology readiness from explorers who are the first to adopt technology to laggards who possess few motivations toward technology and typically would be the last group to adopt a new technological service or product.

Molla et al. (2008) study about what does it take for organizations using IT to succeed in this increasingly low carbon economy and global green movement? Valdebenito and Quelopana (2019) also identify the technology readiness is also a mature index to evaluate an organization's IT and management capability. Mutula and Van Brakel (2006) study figured out when the organization wanted to develop new service or business, its information and digital readiness should include solution for information and communication Technology (ICT) readiness, information readiness, and human resource readiness.

In the progress of entering into environmental sustainability, we define "technology readiness" as "supporting companies' eco demands which have the key driving factors to build up green technology infrastructure and the IT process to support low carbon emission."

Organization Context

Top management support

Gangwar et al. (2015) recognized the top management's role of initiation, implementation and adoption of information technologies. Premkumar and Roberts (1999) found that it is critical to have top management support to create a supportive climate and provide adequate resources for adoption of new technologies.

Salwani et al. (2009) explains top managers' perception and action prone to the usefulness of technological innovation is critical in creating values for the firm. With top manager's precision and actions, it creates long-term vision, reinforcement of values, commitment of resources, cultivation of favorable organizational climate, higher assessments of individual self-efficacy, support in overcoming barriers and resistance to the organization change.

Zhang et al. (2018) study found that even Chinese government has set up several energy policies, many companies still not to adopt proactive energy-saving activities. It indicates that the supporting from top management and through command orders and process will directly impact the companies to take actions on energy-saving activities.

Britel and Cherkaoui (2022) also study the automotive industry cases and find out the major factors impacting the technology readiness are sequentially ranked with top management attitude, employee involvement, resource invested by the organization, organization commitment, organization benefits, easy of organizational change.

Many studies explain commitments and leadership from top management are critical important too. It sets up the organization's vision and policies to ensure the organization can continue aiming to improve the energy system, provide necessary resource, build up cross-functional team, and bridge the communication, involve the employee to take actions on energy-saving (Cagno & Trianni, 2014; Finnerty et al., 2017; Fuchs et al., 2020; Jovanović & Filipović, 2016; Karcher & Jochem, 2015; Trianni et al., 2016).

In this study, we consider the "top management support" is an important factor. We define it as "the commitment and support from top management to adopt energy management system, which provide resource for the organization and belonged buildings to achieve energy-saving and eco-friendly goal."

Organization Readiness

In study by Valdebenito and Quelopana (2019), it indicated the organization readiness is the index of the technology and financial resource. It includes two sub-factors of financial readiness and technical readiness. Financial readiness is the indicator of new system implementation and maintaining cost. Technical readiness is the indicator for maturity of IT technology adoption and management ability. The organization readiness can be used on evaluating whether to adopt cloud service. Only when a company is ready at infrastructure, technology, and financial supporting, then the company will take cloud service as part of the company's value chain activities.

Britel and Cherkaoui (2022) study the automotive industry's adoption of ISO50001 energy management system. They found that if the companies can have the organization readiness as a reference tool, it helps top managers to make decision and define the organization change scope and enforce the supporting actions. It results in lower down the failure risk of organization change.

Digital technology has empowered the organization's innovation capabilities. However, many organizations are still not ready for such innovations due to assessment of investment. Almost 90% of new ideas never been transferred into new products or service. In Lokuge et al. (2019) organization readiness model, it uses seven dimensions to identify the organization readiness which including: resource readiness, cultural readiness, strategic readiness, IT readiness, innovation valance, cognitive readiness, and partnership readiness.

In this study, we define "organization readiness" as "the capabilities and resources for companies to adopt energy management system which including training, financial readiness, organization culture and management process. When companies cannot have necessary technical and financial support to satisfy the innovation request from internal resources, it can also have supports from outside 3rd parties."

Environmental Context

Regulations

Salwani et al. (2009) explore the external factors such as government incentives and regulations that may have significant impacts on a company's business operations. According to D'Agostino and Mazzarella (2019), introduction for new polices with technical and regulatory measures led to more rational use of energy. Such kinds of implementation also reflected on savings of European buildings. Nearly zero energy buildings (NZEBs) is one of the key measures for the index of new buildings. Pumplun et al. (2019) indicates that many laws complicate the introduction and use of AI. A renewal of the legal situation is demanded. The study also points out the government regulations may be both positive and negative effects on innovation adoption.

According to the EU's Net Zero Emissions policy, the zero carbon ready buildings standard will be implemented for all new buildings by 2030, covering both operational and construction-phase energy intensity and emissions (IEA, 2021). This is a demonstration of the government's policy, or regulations that would be accelerated to force enterprises to engage in more transformation activities.

Regulations and governments incentives may drive companies' organization change and innovation. In this study, we define "regulations" as "government's deadline to implement energy reduction and nearly zero energy buildings (NZEBs), and also the government incentives for building companies to adopt energy management system (EMS) or other innovation technology."

Vendor's Support

Dedrick and West (2003) study illustrated the real cases and found that most companies consider the support from suppliers is important. Especially for those big organizations who are used to adopting IT service and maintaining service. With the suppliers' technical support and service, those big organizations will be more intending to adopt new open source software.

Maghsoodlou et al. (2004) indicated that in most automatic power service networks of public utility were set up by system suppliers. And those suppliers collect operation data and operational problems in a long-term period. This makes the suppliers accumulate experience and knowledge which empower strong supporting capability during the system operation. Besides, in topics of service quality control and information security, those suppliers and its consultant play a critical role in improving the operation system.

Gutierrez et al. (2015) study UK's cloud service cases and found that who is the service provider will play an important role for corporations to decide whether to adopt a cloud service. Lal and Bharadwaj (2016) also identified that small and medium company usually worry about whether can trust the suppliers in making decision about adopting a new software system into their mission critical tasks. Thus, the reputation of supplier becomes a critical factor in companies' decision of adopting a cloud service.

This study defines "vendor's support" as "the capabilities of a supplier to provide EMS and technology, deliver knowledge and supporting service." Through the "supplier's supporting capability", it can speed up the setup time, quick to operation, realize the benefits of new energy management system and improve the building's energy efficiency.

CONCLUSION

Energy management system is a significant instrument for increasing a building's energy efficiency, adopting EMS would aid in meeting the NZEB goal. In order to achieve Net Zero Emissions by 2050 Scenario, it is important to study factors influencing adoption building energy saving for promoting zero carbon ready building. Relying on the literature review and interviews, inductive modeling was adopted to build a framework to understand which variables are the critical factors of EMS adoption in building sector. Adopting energy-saving technology is also an important way for building to reduce greenhouse gases. Considering the differences between technology, organization and environment contexts, future research can study detail factors and adoption behavior.

We focus on influencing factors of building energy management system adoption in this paper. The value of such framework and contribution of the paper aim at adopting to new innovated technology and further practice, in order to target net-zero building emission mission. First, the paper examines literature review for effects. Additional, through data collection of experimental interviews with professionals and expertise, a preliminary assumption suggests a perceivable framework tailored. Third, by data analysis to adopt to high advanced technology propose EMS mechanism works for improving building energy efficiency and mitigating carbon emissions as reaching zero carbon ready building. Last but not least, building up a framework and research to excite accepting the deployment and development of new innovated technology, purposely in business grow, optimizing power consumption, and energy saving of the buildings, targeting to zero carbon ready building, and green environment.

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