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NEW TECHNOLOGIES IN ENERGY MANAGEMENT SYSTEMS OF BUILDINGS

Nove tehnologije u sistemima upravljanja energijom u zgradama

Abstract

This paper provides an overview of trends in the application of digital technologies in the energy management system of commercial buildings. In recent years, energy management in buildings, based on digital technologies, has resulted in the reduction in energy consumption of up to 50%. The paper covers trends in the development and application of digital devices and software in various technological areas such as Internet of Things, Edge Computing, Cloud Computing, Big Data, Artificial Intelligence, and Blockchain. Based on the review of the results of the conducted experiments as well as the characteristics of the technologies themselves, automation has been defined as a cornerstone of maximization of energy savings and digital transformation of the energy management system in buildings.

Keywords: *digital transformation, technology, energy efficiency, energy management model, automation, commercial and public buildings, review*

Sažetak

U ovom radu se pruža pregled trendova u domenu primene digitalnih tehnologija u upravljanju energetskim sistemom poslovnih zgrada. Upravljanje energijom u zgradama se poslednjih godina sve više oslanja na digitalne tehnologije, kojima je moguće smanjiti potrošnju energije i do 50%. Radom su obuhvaćeni trendovi razvoja i primene digitalnih uređaja i softvera iz raznih tehnoloških oblasti kao što su internet stvari, edge computing, cloud computing, big data, veštačka inteligencija i blockchain. Na osnovu pregleda rezultata sprovedenih eksperimenata, kao i karakteristika samih tehnologija, zaključeno je da automatizacija predstavlja kamen temeljac maksimizacije energetskih ušteda i digitalne transformacije sistema energetskog menadžmenta u zgradama.

Ključne reči: *digitalna transformacija, tehnologija, energetska efikasnost, model energetskog menadžmenta, automatizacija, poslovne i javne zgrade, pregled*

Introduction

Exponential rise of new technologies has changed the way we live and work. The possibilities that digital technologies provide are fundamentally changing the way business systems are managed. Schwab [53] refers to the current historical moment as the Fourth Industrial Revolution or Industry 4.0, describing it as the integration of physical, digital and biological systems which contributes to the creation of radical and systemic changes in the way of life and work of individuals, organizations and society as a whole [53]. The creation of cyber-physical systems in various areas of life and work, as the main feature of the modern age, is also analyzed in [11], [30], [67]. According to [48], cyber-physical systems are physical and engineered systems whose operations are monitored, coordinated, controlled and integrated by a computing and communication core. A similar definition of cyber-physical systems is given in [4], where these systems are described as a new generation of systems with integrated computational and physical capabilities that can interact with humans through many new modalities. The creation of cyber-physical systems is largely enabled by the intensive development of the Internet and digital technologies in general. Numerous management systems are undergoing a process of digital transformation in order to adapt their way of working to the opportunities and challenges brought by the development of digital technologies. Based on the review of definitions, presented in [57, p. 24], it can be concluded that digital transformation is a process of integration of digital technologies in all areas of management of an organization, which leads to a fundamental change in its overall functioning. Digital transformation is primarily organizational, i.e. strategic, not technological issue [49, p. X], and therefore the organization is required to substantially change its way of working, which should be characterized by short development periods, individualization on demand, flexibility, decentralization, and resource efficiency [29]. Based on an extensive literature review, in [17] is indicated that digital transformation is aimed at improving user experience, efficiency of business processes as well as business models. On the other hand, digital technologies such as Internet of Things, Blockchain, Hyperautomation, Edge Computing, Cloud Computing, Augmented Reality, Artificial Intelligence, Quantum Computing, are just the enablers of these transformations [61]. Many of these technologies find their active use in the field of energy management.

The energy management system is defined in the ISO 50001 standard as a set of interrelated or interacting elements to establish an energy policy and energy objectives, and processes and procedures to achieve those objectives [23]. Noticeable advances in energy efficiency in recent years have boosted progress in decoupling energy consumption from the buildings sector floor area growth. Final energy use in buildings increased from 118 EJ in 2010 to almost 130 EJ in 2019 at an average annual rate of 1%, falling behind average annual 2% expansion in floor area during the same period [20]. Nevertheless, buildings sector energy intensity needs to drop nearly five times more quickly over the next ten years than it did in the past five to be in line with the Net Zero Emissions by 2050 Scenario. This means the energy consumed per square meter in 2030 must be 45% less than in 2020 [20]. Based on the presented data on the current situation and trends, it is clear that achieving the goals of global energy sustainability, as a balance between energy consumption and the share of renewable energy in total consumption [36], is still far away, at least when it comes to buildings. Energy consumption in buildings is mostly related to heating, ventilation, air-conditioning, cooling, lighting, and operation of household appliances and other equipment [46]. According to [20], the greatest progress in recent years in terms of energy efficiency has been made in the field of lighting, while, on the other hand, the consumption of energy for cooling is growing. A big problem is the consumption of energy for the operation of devices, which consume almost 15% of electricity in the world, and only one third of them comply with mandatory standards on energy efficiency [20].

People's interest in providing optimal comfort in the buildings in which they live and work has been present since prehistoric times. Also, with the increase in the importance of energy costs, as well as environmental pollution, the interest in energy efficiency of buildings grew. The beginnings of energy management in buildings were recorded as early as 5,500 BC and concerned the method of building houses so as to ensure a stable internal temperature throughout the year. From then until today, the methods of building facilities, as well as the application of technical measures to improve energy efficiency, have come a long way. In the 1970s, the concept of "green house" was introduced, to be later improved and upgraded through the development of other concepts. All the mentioned concepts have a common goal of minimizing energy consumption while achieving optimal comfort for users as well as independent production of all necessary energy with the use of renewable sources [22].

In recent years, along with the development of technology in the field of energy efficiency, the standards in the field of energy management have been developed. These standards concern both technical specifications in the field of building performance and energy performance and management models of the entire energy system [10], [13], [62]. The ISO 50001 standard, as one of the most recent international standards in the field of energy management, is based on the PDCA (Plan-Do-Check-Act) cycle and represents a suitable framework for defining the model of energy management in buildings. This standard introduces a comprehensive approach in energy management by prescribing the obligation to develop and implement energy policy, establish goals and action plans, make optimal decisions in accordance with energy consumption, measure results and continuous improvements in energy management systems [23]. Measuring the systemic nature of energy management is also the subject of various maturity models of energy management, which aim to analyze the practice in this area, looking for the room for improvement [3], [21], [65]. Basically, both the standard for energy management and the energy management maturity model are in the pursuit of ways to meet the needs of users with the lowest possible energy consumption. Also, the mentioned standards and models point out the necessity for continuous improvements in the energy management system, since the technologies, as well as the user needs, are constantly changing. For this reason, it is necessary to consider the possibilities that digital technologies provide in terms of improving energy efficiency, reducing CO2 emissions and improving indoor comfort and, based on that, to examine the possibility of creating a new energy management model in buildings.

In the following text, based on the literature review, an analysis of the effects of the application of digital technologies in energy management in buildings will be presented. Also, trends in individual technological areas important for energy management in buildings will be described.

Application of digital technologies in energy management in buildings

The application of digital technologies in energy management in buildings has been present in scientific research and practice for more than 25 years [18]. With the introduction of these technologies in the field of energy efficiency in buildings, the primary goal was to create building automation systems, i.e. systems that are an integral part of smart or intelligent buildings. Building automation systems refer to the systems that use hardware (sensors, internal communication networks, controllers, etc.) and software to fully or partially automatically control devices and installations in a building. These systems are widely used in buildings and enable automatic control of home and work devices, as well as the systems related to heating, ventilation, air-conditioning, cooling (HVAC), lighting, water heating, energy production, security, etc. [12] The basis of the energy system automation in a building consists of several processes [2], [8], [12], [44]:

- Using sensors to collect data on the occupancy, behavior and habits of building users;
- Processing of collected data using software and recognizing patterns concerning the occupancy, behavior and habits of building users;
- Software prediction of future occupancy and behavior of building users based on recognized patterns;
- Based on the anticipated occupancy and behavior of users, the controller that is connected to the devices and installations via the network, automatically sends them instructions on the mode of operation to be applied;
- Devices and installations in the building adjust their work to the instructions received from the controller.

Numerous studies have found that building automation systems contribute to a significant reduction in energy consumption. Table 1 presents the results of experiments in the development and testing of building automation systems, in terms of energy savings. These are experiments that are conducted under real-life conditions, i.e. in real buildings or premises.

Based on the experiments shown in Table 1, it can be seen that the building automation system contributes to energy savings of up to 50%. The amount of savings depends on the applied technological solution, type and characteristics of the building (purpose, area, type of construction, etc.) and characteristics of users (time spent in the building, needs for indoor comfort, occupancy, etc.). Successful functioning of the building automation system implies the ability to overcome various technological challenges. Namely, one of the challenges is the ability of the system to collect, process and analyze large amounts of often unstructured data in real time. Also, another challenge is related to the need for the system to be able to adequately store and keep the collected data as well as to predict the future state of the energy system. A special challenge is the networking of smart buildings, where it is necessary for energy management systems in individual buildings to be integrated into the system of several buildings [32], [47], [51], [68]. Therefore, contemporary building automation systems rely on technologies such as the Internet of Things, Edge Computing, Cloud Computing, Big Data, Artificial Intelligence, and Blockchain. An overview of the use of each of these technologies in building energy management will be provided below.

Internet of Things (IoT)

According to estimates given in [33], Internet of Things (IoT) technology will directly or indirectly contribute to the creation of economic value with over USD 11 billion on a global level in 2025. The Internet of Things is described as the network of physical objects - "things" - that are embedded with sensors, software, and other technologies for the purpose of connecting and exchanging data with other devices and systems over the internet [43]. IoT has already found a wide application in the management of energy systems in buildings. This technology is indispensable in creating a building automation system since it collects a number of data relevant to energy management, and then this data is transferred to a place for further analysis and processing. Also, the Internet of Things allows the transmission of commands and instructions to end parts of the system (devices and installations) [7]. The IoT hardware

Table 1: Overview of the results of conducted experiments related to the development and testing of building automation systems

Articles	Results
[2]	The experiment showed that the building automation model achieves 33.1% energy savings compared to the traditional way of consumption.
[14]	By testing the system in three public buildings which are located in climates with different hydro-meteorological conditions, the average savings in energy consumption of the HVAC system of 42% were achieved.
[15]	By testing the system in a public building, it was determined that the system can achieve savings in energy consumption of about 30%.
[16]	Savings of 23.9% in electricity consumption were achieved by applying a lighting controller compared to a system without a controller.
[42]	In the laboratory at the faculty, where the savings in energy consumption were measured, savings between 14% and 30% were achieved, depending on the day when the consumption was measured, i.e. an average of 20% for the entire month of the experiment. In the commercial building, where the savings were also measured, the average energy savings for cooling and lighting in the amount of 23.12% were achieved.
[44]	Compared to the manual system, the automatic system achieved 10% savings for total energy consumption, with 25.6% for thermal energy, 16.5% for lighting and 6.2% for auxiliary electric energy.
[45]	Energy savings of electrical appliances of 46% in the home and 61% in the office were achieved.
[59]	In the period when the system was installed, there was 27.5% lower electricity consumption compared to the period when the system was not installed.
[60]	The automation system, developed as part of this research, contributes to a 56% reduction in device usage and a 50% reduction in energy consumption.
[71]	The measured results indicate that the smart HVAC system achieved energy savings of about 14%, while the control system for energy consumption of electrical devices contributed to a reduction in consumption of 33%.

requires operating systems and communication protocols to interact with human (user) and other devices. There are middleware components that facilitate communication and exchange of information between devices. In IoT architecture, integration layers play an important role in combining and integrating information acquired from thousands of devices and presenting this information to users [25]. IoT technology in energy management includes several key elements:

- Sensors. These serve the purpose of measuring parameters such as temperature, humidity, lighting levels, and room occupancy. The IoT plays a role in facilitating the injection of smart "things" in the environment.
- Controllers. These develop the system's response - the response is synthesized from the data that is collected by the sensors by applying appropriate optimization algorithms.
- Output devices. These actually implement the commands received from the controller [37].

For a building energy management system to be fully operational, it is imperative to have real-time robust information flow from a variety of heterogeneous sensors deployed within the building, presenting the current building operation (e.g. energy consumption, environmental conditions, occupancy, etc.) [6]. According to [5], the design goals of sensors deployment are as follows:

- Low power consumption. It is desired that the deployed sensors and/or controllers do not consume significant power impacting their life (when powered from a battery) or utility (when powered from mains) [5].
- Wide network coverage. For collecting spatially distributed information, more than one end controller or node may be deployed. Often, these end nodes relay the collected data to a central node or gateway for storage or further processing. The deployment must ensure that all nodes are within the communication range of at least one node and together cover the whole area that is to be monitored, under different real world scenarios. Often, multi-hop strategies are used to increase network coverage [5].
- Robust. The real world presents many unforeseen challenges which the sensor deployment must account for. It is often desired that the system is capable of easy healing and recovery [5].
- Ease of deployment and maintenance. Ease of deployment and maintenance outside the controlled settings has always been an important challenge and design goal of sensor network deployments [5].

An integrated IoT system allows the building manager to monitor and sense the building's different environmental parameters (e.g. through motion and noise detectors, temperature and humidity sensors, and electricity and water flow meters), collect the relevant human activity information (occupancy, heat map, etc.), and estimate the energy usage (e.g. by comparing the current information with previously collected historical data), which will be fed into a smart management system that will manipulate actuators (e.g. switches, controllers, and thermostats) to efficiently manage the building's environment according to expectations and designated rules. Such an IoT platform (which is an open platform) can interface and connect with various subsystems of different vendors, e.g. sensing subsystems (people counting, temperature, humidity, light, noise, and motion), control subsystems (thermostats, switches, smart plugs, and actuators), and metering subsystems (energy consumption, water flow, etc.) [63].

The 5G network represents the fifth generation of mobile internet, which implies higher speed and signal quality compared to the previous generations, but also completely new features. These new features include greater capabilities for connecting multiple devices via the Internet of Things, reduced latency in communication between devices, and the ability to process large amounts of data in real time [9], [19]. With billions of devices connected to the cloud, 5G will play a crucial role in reducing energy consumption and shaping new processes and applications, leading to better energy efficiency [9].

Edge Computing

The development of technology and lower costs of its use in the domain of the Internet of Things have led to the greater use of sensors in buildings as well as the diversity and amount of information they collect [70]. Solutions that involve centralized system architecture, based on uploading, storing, processing and analyzing data in cloud systems, are not able to effectively track the aforementioned increase in the amount and diversity of information. In this regard, it was necessary to develop a technology in the field of energy management which will be accurate and able to complete processing and analysis with the lowest possible costs, without congestion of the system, and without latency [35]. The solution was found in the form of Edge Computing. This technology implies that the functions of data processing and analysis are performed on the "edge" of the energy system, i.e. almost in the devices that collect data, which makes the system decentralized. In this way, there is no transfer of data to a central database for data processing and analysis, but all of them are processed and analyzed in different devices in the system [56], [69]. The ability of devices, in addition to collecting, processing and analyzing data, was created using embedded software, which is often based on artificial intelligence [35]. Although this technology in energy management does not eliminate the need for Cloud Computing, it still relieves the system and improves its manageability [31].

Cloud Computing

The large amount of data collected by sensors within the energy system of buildings must be adequately stored, processed, analyzed and stored in order to create optimal models of energy management. It is often expensive and not efficient enough to perform all these operations in-house, i.e. on their own servers. Cloud computing is a set of services which provide users with the ability to store and share their data among themselves on dedicated Internet platforms. Also, within the mentioned platforms, it is possible to access various software intended for processing and analysis of collected data [24], [38], [55]. Cloud computing is an on-demand computing model that eliminates or reduces the need for companies and organizations to have in-house high-cost software, hardware, and network infrastructures [40]. Cloud computing can provide many advantages for smart buildings' energy management systems such as providing the required software models that implement different control and monitoring algorithms and providing optimization methods for more efficient energy consumption in smart buildings [39]. When IoT is integrated with the cloud, real-time service can be provided extensively, and a huge amount of data is produced, which requires a huge amount of storage space that can be provided by the cloud. The management of energy in a cloud platform allows users to easily access the energy management system through public or private clouds via a Web browser or application programming interfaces (APIs) [52].

Big Data

Digitization, which is present in all areas of life and work, contributes to the generation of a huge amount of data. Therefore, data is a potentially important organizational resource, but in order to use it in the right way, it is necessary to have the ability to turn the data into information important for making optimal decisions. It is for these purposes that the Big Data concept is used. This concept entails modern technology and methods, which concern the processes of collecting, organizing, processing and analyzing often complex and unstructured data, given in sets of huge dimensions, where the above processes are performed faster than by using traditional concepts [1], [27], [34].

The development of the Internet of Things has contributed to the creation of sensors capable of collecting a variety of energy data in buildings. The diversity of these data is present on several levels. On the one hand, these data can concern the interior of the building (indoor temperature and humidity, occupancy level, energy load and consumption, etc.), as well as the data from the external environment such as weather conditions [1], [34]. On the other hand, data can be collected at the level of the entire building, floors, rooms, and even individual users and devices [1], [34]. The sensors used in the energy management of buildings have the possibility of continuous operation, and thus a continuous data collection. By deploying a large number of sensors in the building, a huge amount of data is collected, and it is constantly increasing [1], [41]. At the same time, in order to keep the energy system aligned with internal and external factors, it is necessary to process the collected data on a daily, hourly, and often real-time basis [1]. Based on all the above, it is obvious that energy data meets the three main Big Data criteria (Variety, Volume, and Velocity) [1].

The purpose of collecting and processing energy data is to better understand the characteristics of the building's energy system, external and internal factors that affect it, as well as the needs, behaviors and characteristics of users [27]. In this way, a basis is created for predicting the future state of the energy system and, accordingly, making optimal energy management decisions. The integration and development of systems based on the Internet of Things are important enablers of a wide range of applications, both for industries and the general population, helping to make smart buildings a reality [41]. That is why the development and implementation of Big Data must keep pace with the development of the Internet of Things, in order to ensure data-driven management of the energy system in buildings and maximize energy efficiency.

Artificial Intelligence

Artificial intelligence is a machine (computer) simulation of processes that form the basis of human intelligence, such as learning (gathering information and rules on how to use it), understanding (using certain rules to draw appropriate conclusions based on available information) and corrections (independent reaction to changes in the environment and adaptation to them) [28], [54], [66]. According to [66], a typical AI based prediction method in energy management in buildings contains four main steps:

- The first step is to acquire historical input and output data. The input data are the aspects that impact or correlate with the output data. These aspects include, but are not limited to the following: exterior weather condition, occupants, global heat loss coefficient, and day types. The output data are those parameters that represent building energy consumption. The sampling periods of both inputs and outputs vary from year to minute according to the prediction time scale of the research [66].
- The next step is to preprocess the collected data into a suitable format before they are used to train the prediction model. To some extent, the initial data may not be able to be used directly by the model. Some data preprocessing techniques such as data transformation, data normalization, and data interpolation are applied in this step to improve data quality and reduce a negative impact [66].
- Once the data is ready, the third step is to train the prediction model. Since the key concept of empirical modeling is learning from historical data, a training process is required to develop the model. This step is achieved by selecting appropriate parameters for the model. The parameter selection is impacted by the size of training data, the selection of input variables, and the performance indicators [66].
- The last step is testing the model. In this step, testing data will be loaded to the trained model to test the prediction performance of the model [66].

Within the described concept, it is important to pay attention to its most prominent branches, machine learning (ML) and artificial neural networks (ANN).

Machine learning involves the development and application of algorithms that enable computers to, automatically and without human intervention, collect and process data, and create relevant information of importance to users. ML models operate as a black box and need no information on building systems [54]. They discover the relation between various input features and output targets (e.g. energy performance) using given data. When the ML models are trained with enough data, they can be used to predict targets for unseen samples, though the relation between the features and the targets is not defined. In this case, the targeted energy parameter is calculated using simulation (in general engineering method) or measured and used for training the model [54]. Another method of ML is mainly applied to unlabeled data to cluster them based on hidden pattern and underlying similarities in features. This method is very beneficial for the application of energy benchmarking where a determination of baseline buildings is crucial for calculating the energy performance of similar cases [54].

Artificial neural networks, as a basis for the development of artificial intelligence, are computer systems, created based on the model of neural networks that exist in the human brain. In other words, these are systems of connected process units, which, based on given rules and templates, adopt and process information from the outside world and then create the result in the form of reports or decisions [50]. When it comes to the application of ANN in energy management in buildings, numerous studies have confirmed its effectiveness in terms of heating and cooling loads estimation, prediction of indoor air temperature, prediction of energy consumption, and energy management modeling. With an adequately trained system, prediction accuracy is over 99% [28].

Blockchain

Energy management in buildings nowadays goes beyond individual buildings and is increasingly viewed in the context of optimizing energy consumption at the level of several smart buildings. Namely, in order to lower costs and increase the reliability of supply, many organizations, within their buildings, also produce energy from renewable sources, which they then use for their own needs. These organizations are called prosumers. However, the energy produced can also be traded between organizations using blockchain technology. In this way, overall, it is possible to achieve savings in energy production at the community level, i.e. the energy produced is properly distributed so that there is no loss [26], [58], [64]. Blockchain is a distributed ledger technology which is managed by peers on a peer-to-peer network. This technology exists without a central administrator or centralized data storage. Data could be spread across several sites and the data quality is maintained by replicating and encrypting the database [26]. Various examples of blockchain technology application in the energy management are given in [58]. Regarding energy efficiency in buildings, for example, virtual coins or green certificates can be created to reward renewable energy producers or rational consumers, in order to promote production from renewable energy sources, decrease of consumption or load shifting. It is also possible to set up a local energy market between producers and consumers using virtual currency [58]. The community encompasses the local energy actors, the physical power system through which electricity flows, and the energy management mechanisms. A common approach consists in using a local aggregator to centrally collect flexible building parameters and renewable energy sources data to optimize a given objective, both in planning and real-time operations. A decentralized approach implies that without the aggregator agent, the goal of the community is to agree on a consensus that optimizes a given shared objective function. The aggregator is entirely replaced by the Blockchain environment and every energy actor only interacts with the Blockchain [64].

Discussion on the application of digital technologies in energy management in buildings

This paper shows that automation systems in buildings contribute to significant energy savings in commercial and public buildings. With the development of digital technologies, these systems become more precise, more reliable and easier to manage, and contribute more to greater overall energy savings. Namely, the energy management system today involves collecting data via sensors and smart meters (Internet of Things), their processing on the spot (Edge Computing), their storage and additional analysis (Cloud Computing), analysis of large amounts of collected diverse data (Big Data), consumption forecasting and automatic taking of actions based on collected data and projected consumption (Artificial Intelligence), and energy trade between several networked buildings (Blockchain). With such a defined system, the aim is to reduce human participation in the building energy management system, i.e. to create the management system which would be largely under control of artificial intelligence. However, having in mind the users' preferences, it is possible that the management will be only partially automated, i.e. that users will retain the possibility of independent management, based on the data collected. By applying automated energy management systems in buildings, it is possible to eliminate irrational consumption or human errors that can lead to energy consumption which is higher than optimal.

Automation of the energy management in buildings provides an opportunity for organizations to collect and analyze data on various parameters of the energy system, as well as to predict future consumption, costs, carbon dioxide emissions and so on. The availability of this information gives organizations the opportunity to respond more effectively to the requirements of energy management standards, such as defining goals, strategies and plans, monitoring indicators and taking measures for improvement. Also, through automation, the energy system adapts its work to the needs of building users while striving to minimize energy consumption. In this way, organizations are relieved of the burden of managing this domain and have the opportunity to focus more on their primary activities. Accordingly, the automation of the energy system in commercial buildings contributes to both greater organizational efficiency and more successful implementation of business strategies.

Conclusion

Digital transformation is one of the most important features of the modern age. The application of digital technologies introduces significant changes in all areas of life and work, most often in terms of improved efficiency of organizational processes and greater customer satisfaction. However, another feature of the modern age is climate change, whose negative impact is most often stimulated by the emission of carbon dioxide due to the combustion of fossil fuels used in energy production. Buildings are significant consumers of energy in the world. All of the above has imposed a need on organizations to improve energy efficiency in their buildings.

In the mid-1990s, in both science and practice, a more intensive research effort began in terms of creating building automation systems to optimize energy consumption. Based on the analysis of experiments conducted in the last 10 years, it was determined that the application of digital technologies or, more precisely, the building automation system in energy management in buildings, contributes to energy savings of up to 50%. This system reduces the possibility of human error and irrational energy consumption, and also, thanks to the collection of diverse data and learning abilities, the system adapts to the needs of users.

Future research in the field of digital technologies in energy management of buildings should be focused on:

- Development of more precise sensors with lower probability of failure;
- Implementation of a 5G network to make machine-to-machine communication faster and more reliable;
- Improving the ability of artificial intelligence to anticipate and undertake activities in real time to adapt the energy system to ever-changing circumstances;
- Further development of embedded software in building energy management system;
- Taking the opportunities that blockchain technology provides in the field of networking buildings in smart communities.

Also, there is room for further research when it comes to integrating the energy management in buildings with the strategic management of organizations. Namely, it is necessary to explore the impact of various organizational factors on energy efficiency in buildings and, accordingly, to complete the digital transformation of the energy management model.

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