Internet of Things and Big Data Revolution in the Context of Green Technology

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Abstract. *Sustainability and energy consumption have been a debatable issue in the adoption of IoT-based technologies and Big Data in the energy sector. One of the solution to energy sector can be carried out through the improvement of the energy-efficiency use with the adoption of IoT and Big Data into the energy management system. However, several aspects require specific attention, particularly the readiness and capability of the organization from the infrastructure and managerial perspectives.*

Kata kunci : *IoT, Big Data, Green Technology*

1. Introduction

The future of technology with its current rapid developments on the information and communication technology holds a very important aspect in human's life. Broadband network has been extensively accessible for public, and more sensors are integrated to the newly manufactured devices for them to connect to the internet, giving the assistance to the emergence of the *Internet of Things* (*IoT*). The term of "Internet of Things" was probably conceived for the first time at Procter & Gamble (P&G) presentation by Kevin Ashton in 1999 [1]. In the later time, it was defined as an internet radical evolution where network of interconnected objects create a smart autonomous environment [2]. The definition may expand as far as the interconnection of sensing and actuating devices capable of sharing information through a consolidated framework beyond platforms, where creation in common operating picture in smart environments encourage innovative applications [3]. The earliest idea was the empowerment of computers to learn, see, hear, and smell the world autonomously for thrusting the process of information collection. This possibility has been made wide open through the invention of sensor technology and RFID, enabling the computers to perform beyond the limitations of human-entered data [1].

Certain circumstances are required for technology to work underneath the users' consciousness. For this purpose, the IoT demands a bilateral understanding of the situation between the appliances and the users, pervasive communication networks and the software architectures to convey the contextual information, as well as the analytics tools intended for smart and autonomous behavior [3]. In short, things associated with IoT should be *aware* (i.e. sense something), *actionable* (i.e. integrated for analysis and control), and *autonomous* (i.e. automated data transfer over the internet services) [4].

A brief explanation provided by Lee et al. [5] mentioned the fundamental characteristics of IoT that include: (1) Interconnectivity, where any devices have the potential to be interconnected to the communication infrastructure, (2) Things-related services, describing the capability of IoT to provide thing-related services within the constraints of the devices, (3) Heterogeneity, emphasizing the heterogeneous range of devices from tiny sensors to large computers, (4) Dynamic changes, illustrating the capability of devices to be dynamically changing status (e.g. sleeping/waking, connected/disconnected), and (5) Enormous scale, where the number of the interconnected devices keeps increasing.

The common target of the IoT is the expansion on the number of interconnected devices per individual to the order of thousands [4] with more devices in the industries equipped with sensors. In 2013, the number of the interconnected devices was recorded at 9 billion units, and it has been expected to increase tremendously to 24 billion devices by 2020 [3]. As a result, one of the most anticipated outcomes on the emerging of IoT is the generation of large data volumes, which by 2020 was forecasted to be over 40 trillion gigabytes (or 40 yottabytes), where special manipulation to provide meaningful information is needed [2]. This leads to the increased adoption of IoT with an impact to the generated volume of data, transforming the collected data into "Big Data", a term describing a large, both structured and unstructured, volume of data.

Sustainability and energy consumption have become debatable issue for the generation of Big Data. The massive amounts of data produced, where IoT devices were forecasted to account for 10% of the worlds' data in 2020, has an overall power consumption that could become 25 PWh, comparable to the expected total worldwide energy production [4]. The generation of large amounts of real-time data that causes inclined power consumption has been pushing the internet towards its limit, and thus it has to be restructured in a more decentralized manner to ensure the sustainable scalability [4].

In the context of sustainability, utilizing Big Data resulted to a distinctive approach in cutting wastes and carbon footprints, enabling businesses to use more sustainable materials, cut emissions, and reduce the material impact. The key is that the new data-driven strategies should assist many companies to optimize their performance by gathering and analyzing data through the whole product lifecycle. In the framework of green technology, Big Data can also be used as a tool for environmental preservation, responses to climate changes, smart grids, and smart cities.

2. Big Data Concept

Big Data has been exemplified as a massive amounts of data that are too complex to be governed by normal processing applications [6] where current methodologies and data mining software tools fail to manage due to their large size [7]. The term was first coined in a 1998 Silicon Graphics (SGI) slide deck by John Mashey with the title of "Big Data and the Next Wave of Infra Stress" [8]. The first academic paper related to it was first published in 2000 by Diebold, and the related topic of Big Data mining was published into a book in the former years of 1998 by Weiss and Indrukya [7].

The ever-increasing data size can be seen from the astounding data numbers over the internet usage, among them: Facebook has more than 800 million updates per day, Twitter has more than 250 million tweets per day, YouTube has more than 4 billion views per day, and Google has more than 1 billion queries per day. The estimated data produced was in the order of zettabytes and it was growing at about 40% every year [7]. The continued improvements in the capability of high-resolution sensing and high-performance computing have led to unprecedented complexity and size of data. Today, data has been deemed as a powerful raw material that capable of significantly impacting multidisciplinary research [9].

The digitalization of data itself bring certain opportunities for many organizations. The one should be highlighted is the improvement on the efficiency of production processes, thus resulting in the cost-savings through resource optimization attempt. A better efficiency of the information flow and logistics can be also added into the list, opening-up for new business opportunities. The last point is the capability in bringing customer closer with better tools for customer ties and retention.

2.1. The characteristics of Big Data

Over time, the method in which data is stored, transmitted, analyzed and visualized has been steadily varying. Together with the development of the industries, the socio-economical arrangement, and political situation, the human activities are always connected with the increase in technological possibilities. As the sets of these data grew enlarged into what today called as Big Data, the attached characteristics of this entity has been constantly developing.

There were at first three characteristics (also known as 3 V's) of Big Data which include (1) Volume, that describes the constantly increasing amount of data than ever before, (2) Variety, that describes data type variations (e.g. text, video, sensor data, etc.), and (3) Velocity, that defines the continuous stream of data arrival. Two other characteristics were added in the latter time that cover (4)

Variability, which defines the changes in the structure of data and how the data can be interpreted, and (5) Value, that defines the competitive advantages could be gain from analyzing the data [7].

These days, Big Data includes the complex, huge, and abundant structured and unstructured data. One aspect that makes it potential raw sources of information, is the fact that it is generated and gathered from several fields and resources. Aside of that, the enormous volume and complexity characteristics of this data sets propel technological advancements in realizing the exponential increment in storage capability, transfer velocity and bandwidth capacity, as well as the processing power [6].

Data variety has been steadily expanding, as the last few years have been recording the significant increase in the amount of data available from many disciplines. The data generation velocity has been also increasing due to the proliferation of IoT, and sensors connected to the internet. This provides opportunities for businesses across all industries to gain real-time business insights.

2.2. Reaping the benefits from Big Data

Since the world data is expected to grow by four times in 2015 – 2020, the IoT can be considered to be responsible for the data overflow that impact the network traffic. Only 1% of enterprise data is being processed for valuable knowledge, and it has been expected to further worsen, since the volume has been steadily increasing [4].

However, this does not negate the potential of Big Data as the raw material for many business optimization processes that could lead to the performance improvements. In the manufacturing industry, Big Data exploitation can decrease product development and assembly cost to approximately 50%, coupled with 7% working capital reduction [2]. In order to reap the benefits from the application of IoT for Big Data mining, the vast amount of information requires a special manipulation and analysis to provide a meaningful reasoning and actual value extraction. The focus of the approach is the predictive analytics that has been utilized for capturing the data relationships and discovering the patterns. In short, the whole process to gain the benefits from Big Data include data extraction, analysis, visualization, storing, sharing, searching and transfer processes.

The benefits are reflected when data was generated by the lower level of enterprise, directly from the devices and the users. The data is the critical ingredients for analytics to provide meaningful information for the higher levels of the enterprise, thus assisting them with a good adaptivity and flexibility in decision making [2]. This is particularly true for the real-time data analysis that has been embedded into physical systems, thus enabling new configurations of autonomous control. In return, sustainable applications, resources saving, and waste reduction exercises can be improved [9].

Another alternate scenario, observations and study by Gunther et al. [10] argued that big data also allows organizations to radically change their business strategies and to transform into new industry contexts. In a different way, it can be done by innovating their business models to monetize data or insights by trading and selling them, or by enhancing customer experiences through new value propositions.

However, it is important to highlight that the extent to which organizations adopt big data, taking the possible profit, and capable to innovate really depends on the size of the organization and the nature of the industry. In particular, it takes development of capabilities to move from one stage of big data maturity to another where mainly large organizations have the resources.

3. Vision and Impact Towards Green Technological Developments

The Internet of Things assimilated to all lines of business, industrial, academical, and non-commercial activities, with application ranged from small to big, and local to global-wide scale. The energy sector was not an exception, and the related industries have been adopting it together with the growth on the revolution of data. The expanding number of IoT devices has been assisting the field job execution through the deployment of millions of sensors and RFID for data collection (e.g. environmental data of temperature, humidity, etc.), assisting not only the field executor through automated processes, but also to provide a better insight in data reading and analysis for a more accurate decision-making process. A better set, complete, and accurate data should always assist the whole critical processes undergo by an organization.

There were immense consequences arising from the emergence of these information technologies advancement and their adoption towards the development of green technology. For most, they span around the technological challenges and management aspect of the energy sector. One very particular impact was the data volume outbursts, generated from millions of sensors deployed in the green industries. Adjustment in management is required, and organizations have been bound to follow the changes by finding a way to govern the challenges arisen from the adoption of these new technologies. In return, the adoption of IoT and Big Data revolution for green technology and energy sector should be proven to be beneficial.

3.1 Manifesting the Green Technology Vision into the Fourth Industrial Revolution

The fourth industrial revolution, also known as the Industry 4.0, can be explicitly seen as a reference to the digital dimension of the upcoming industrial structures. It fosters the integration of cyber-physical systems and IoT-based technologies into what can be referred as smart factory [9]. Some believed that the term itself was an invention of German Research politicians aiming to circumvent cumbersome headlines of the “cyber-physical systems” [11]. Regardless, the essence is the embodiment of the smart industry through the application of high technology with the advanced information and communication systems [12]. The direction was the comprehensive interconnection from all elements of the value-added process, from the early stage of raw materials and pre-products, customer interconnection, as well as the service processes and the logistics.

Despite of the potential in delivering disruption to the manufacturing sectors, the Industry 4.0 has a higher ambitions aimed towards the energy and resource efficiency, networks value integration, increased productivity, end-to-end digital integration, and the shortening of time-to-market and innovation cycles [13]. However, it requires special needs on the new notion of information management and business administration. A good example on the implementation of IoT-based technologies for business administration can be seen from the Republic of Estonia with the issuance of “e-Residency”, where management of information streams and business administration issues can be tackled through the integration of small and medium-sized enterprises sector into international supply chains. Estonia can be considered as the first country in offering transnational digital identity to those who is interested in administering a location-independent online business.

The Industry 4.0 leads to the new paradigm of a new supply chain based on intertwined and complex manufacturing networks, thus delivering great robustness and flexibility in pursuing the efficiency of energy and cost reduction, as well as cutting the carbon footprints.

Duarte & Cruz-Machado [12] investigated the Lean and Green Supply Chain in the Industry 4.0. In a brief way, the lean paradigm should improve the productivity and quality through waste elimination, as well as cost and time reduction. In parallel, the green supply chain paradigm reduces the impacts towards the environment while eliminating the wastes in the organizations, thus improving the ecological efficiency. The study was made due to the lacking evidence on how the lean and green supply chain would evolve to efficiently adopted and work in the environment of Industry 4.0, and at the opposite to check the capability of Industry 4.0 in supporting the implementation of the lean and green supply chain.

The results were conclusive that, without a doubt, the Industry 4.0 was already based on the characteristics that lean and green supply chain already focused. The adaptation of these technologies can be made through the product and process design, manufacturing planning and control, information sharing, logistics and cooperation with suppliers, as well as energy and customer value [12].

3.2 Smart energy management with Big data

The solution to energy sector mainly comes from two major aspects, which is either the development of renewable energy sources, or the improvement of the energy-efficiency use. The adoption of IoT and Big Data will not lead to the generation of renewable energy sources, but rather can be considered as a powerful tool for the latter option. The aim is to provide a reduction in the energy consumption, and at the same time reducing the operating costs of the working energy system.

The process can be conducted with an implementation of smart energy management through the integration of many IoT devices, components, and sensors to generate data from the field. This involves a continuous adjustment of the operating parameters for changing environmental variables (daylight intensity, temperature, variable traffic, etc.). The data should then be stored and analyzed to provide suitable decisions and responses.

Many things require adjustments in adopting the Big Data for sustainability in the energy sector. In general, energy-efficiency can be attained when Big Data mining and analysis enhance the knowledge repositories, thus improving the decision-making in many different stages of energy management sector. For this approach to take an effect, the traditional way on handling the large data sets has been obsolete. The analysis approach should change from being structured, static, and centralized to being mixed-structured, real-time, and distributed.

Framling et al. [14] argued that for a system to be energy efficient and ubiquitous, it is necessary to exchange information and coordinate action between the systems that have conventionally not been interoperable. The task is to implement a way to collect the relevant information by the underlying systems, e.g. real-time sensor readings, as well as the capability of taking further actions based on the information taken. It is believed that the instance-informed information system is the cornerstone for achieving energy efficiency, by collecting and analyzing the energy data sets to support the constant optimization of energy efficiency.

There are two components in Big Data that equally important to achieve the energy-efficiency and optimization process for smart management system. They are similar but should be defined in a different way. Green information technology (IT) is the first component that has been focusing on the process of computing infrastructure to be more energy efficient. Another component is the green information system (IS) that has been defined as the design and implementation of the information systems that assist the sustainable business process [14]. The second component holds higher importance in the establishment of smart energy management system, whereas the implementation has been widely assimilated to many industrial sectors.

Other approach towards energy management was made by Cao et al. [15] with a comprehensive study in Energy Internet. The first concept itself was introduced for the first time in 2012 by Jeremy Rifkin for World Financial Review [16]. The term was originally designated for the coupling concept between electric power system and other system, where the electric power system lies as the conversion hub between the various forms of energy and act as the core of Energy Internet. The aim was to fully utilize the distributed renewable energy sources, as well as improving energy efficiency and electric power system reliability. This system is rather known for its integrated energy supply system, with peer interconnected sharing network features between power electric technology, novel energy technology, and information technology.

Cao et al. [15] included the observation on the combined cooling-heating and power system, coupling of electric power system with natural gas system, and integrated electric and traffic system in the study. Their results showed that Energy Internet supports the concept of sustainable multi-energy system, where continuous development, convergence distribution of energy sources, diverse forms of energy (i.e. gas, heating, cooling, electricity), supported by the data sets from the internet, may lead the sustainability towards a steady improvement trajectory.

Many management methods may not be covered, and may be altered from one organization to the others, according to the circumstances encountered. However, it involves the method on dealing with huge amount of data, mining the necessary ones and analyzing it for decision-making purposes. In the smart management of energy where devices and sensors are employed, the critical processes should be highlighted are the data acquisition and analysis.

3.3 Big Data application for the green technology framework

Big Data application in the energy sector widely spread in many sub-sectors, from electrical appliances, automotive-related appliances, stretched to renewable energy systems. The scale may also differ from local to a, rarely, nation-wide scope. The following are several cases that follows the implementation of IoT and Big Data technology for energy sector.

An example on how Big Data was utilized for energy monitoring system, visualizing the actual energy consumption of a house in real time has been developed at the Electrical Building Services Centre (Porvoo, Finland) [14]. The user may instantly check the energy consumption through a constantly updated graph on a web page. The data visualization makes it possible to see the effect of various energy saving measures, and instantly receiving feedback on how the consumption rate is affected by the turning on and off electrical devices. The study was conducted by Framling et al. [14] where it also covered the application of instance-informed systems with the implementation for automotive sector. This comprises the remote monitoring of vehicles which later provide significant savings in maintenance and repair cost, changes in driver behavior, as well as the optimization of fleet vehicles. All these benefits are important in the perspective of green technology information system.

Another study in the power and electrical appliances was conducted by Fischer et al. [17], by utilizing the placement of a simple sensor kit, with a set of temperature, light, and humidity sensor in a single networked device, in the house of their clients. An advisory attempt was made by furnishing the advisors with visualized data to discuss with clients during an in-home visit. This method enabled the advisors to explain the client’s problems and their potential causes, as well as identifying energy-related issues associated with their house.

Other attempt was also made by Ozadowicz & Grela [18] by proposing a new approach in the functional strategy aimed to control high pressure sodium lamps for the street lighting control system, where an extended application was made by classifying four efficiency classes of building automation and control system (BACS) as defined in the EN 15323 standard. The results were proven to be positive with a significant potential in energy consumption reduction. In particular, the energy reduction can even reach about 45% saving compare to conventional street lighting system.

The building automation and control system was observed and proven to influence the electrical energy consumption. However, another level for significant improvement can still be expected with more advanced and well-organized street lighting control systems. This is also to highlight the possibility of integrating outdoor lighting system into BACS for information exchanges with other systems (e.g. Smart metering). Further integrations may even allow the merging of public spaces lighting system with other larger scale elements such as smart cities and smart grids infrastructure [18].

An increased scale in the study of Big Data application was made by Zhou et al. [19] in a comprehensive study on Big Data-driven smart energy management, in which they come with for aspect of discussion in (1) power generation side management, (2) microgrid and renewable energy management, (3) asset management and collaborative operation, an (4) demand side management (DSM). They emphasized another perspective on Big Data as a reminder that energy big data does not only include the massive smart meter reading data, but also the enormous amount of data from other sources, such as the weather data, the asset management data, and the GIS data.

In building applications, Koseleva & Ropaite [20] investigated the application of Big Data for building energy efficiency, where they argued that Big Data analysis is one of the methods used to analyze the individual’s energy consumption behavior, and thus helping to improve energy efficiency by promoting the energy conservation.

4. Future Challenges and Directions

Despite of the wide applications, the IoT and Big Data revolution are currently at their initial stages for adoption and development. In a specific way, they conform to the innovators adoption stage. In a large scale, they have been applied broadly for the industrial applications, sustaining businesses and enterprises achieving efficient productivity for a sustainable production processes. Yet, it is believed that the next impact of both technological uprisings will penetrate the smart homes sector as the second-large scale application after the general industry. The new capabilities will be introduced are probably in terms of security, lighting, appliances, heating and conditioning system, as well as assisted living. Further forecast by Alioto [4], beyond the smart homes, envisioned the third wave of the Big Data technologies to serve the transition towards smart buildings and then smart cities, as a standardized achievements in smaller settings can be a valuable base to grow to the bigger scale.

In terms of challenges, according to Koseleva & Ropaite [20] who have analyzed the possibility for Big Data analysis in building energy sector, three main issues should be addressed. They are the very big amount of information that involves several dimensions, the method for taking out the data in a short time, and the limited existing applications to process the data. These challenges should be addressed immediately to efficiently promote the energy conservation and the efficient energy utilization.

In a similar way, Framling et al. [14] emphasized the new challenge in the IoT context over several points. The information systems which produce, process and store the information that rather to be distributed over different computing devices was the first to be highlighted. Particularly when those information systems belong to different organizations and where things probably mobile, as mobility may cause certain technical issues due to intermittent connectivity to the network. Another highlighted issue was the information management collected by millions of embedded sensors and computing devices related to the physical product they were mounted on. The embedded sensors can be just an identification device, where the instance information needs to be stored remotely.

In a different perspective based on the study of smart grid in energy sector, Zhou et al. [19] summarize the challenges in the energy sector that covers the operational efficiency and cost control, system stability and reliability, renewable energy management, energy efficiency and environmental issues, as well as consumer engagement and service improvement. It was argued that the severe challenges for the utilization of Big Data in the energy sector cover:

1. Information technology (IT) infrastructure; where it involves the improvement in network transmission and data storage capacity, as well as data processing, data exchange, data visualization, and data interaction capability to better support big data.

2. Data collection and governance; where the energy big data management requires complete data governance strategies, as well as neat organization and control procedures.

3. Data integration and sharing; with many barriers can be found on the integration and sharing of energy big data from various sources, with different data definition, storage, and management standards and models adopted among different energy companies and organizations.

4. Data processing and analysis; with effective and efficient big data processing and analysis techniques as the premise and important assistance of the many smart energy management tasks. It was found that traditional and conventional data analysis techniques in data mining, machine learning, statistical analysis, data management and data visualization have encountered some difficulties in dealing with the energy big data.

5. Security and privacy; where the energy system is vulnerable to be attacked with a lot of privacy information involved. The consideration is for the security mechanism to be further improved to protect the privacy of sensitive costumer data, where the consumers have the right to own their data.

6. Professionals of big data analytics and smart energy management.

Responding to the arising challenges in the application of IoT-based technologies and Big Data revolution, several anticipating steps should be taken to direct the system for optimum future execution. According to Cao et al. [15], the main directions for the future research of the IoT application in the energy sector should cover (1) the optimal coupling of multi-energy systems, (2) secure operation of energy management through advanced information and communication systems improvement, (3) coordinated nation-level management and policies for the global energy system, and (4) demonstration projects for a larger scale implementation of Big Data on global energy system.

Regardless the challenges arising from multiple backgrounds and circumstances in the energy sector, most users and organizations seems to have an agreement that an improvement should be made in terms of hardware and devices quality deployed on the field for a better efficiency energy usage. Other than that, improvement towards data storage and management are also crucial, as certain studies found that the current system is incapable to keep up in handling the large amount of data generated in an exponential basis. The very last major thing that still hinder the utilization of Big Data in energy sector is the mining process and analysis of the data in interest. This is also to highlight that data visualization is important, and currently there are limited number of professionals dwelling into this matter.

5. Conclusion

The arising IoT-based technologies and Big Data revolution have been affecting the energy sector and assimilating in a way that major changes could not be evaded. With the immense consequences arising from the emergence of these transformation, an adjustment in the management system is required, and organizations should find a way to overcome the challenges arisen from the adoption of these new technologies.

The adoption of IoT and Big Data has been aimed to provide a reduction in the energy system operating costs and the energy consumption. The process can be conducted with an implementation of smart energy management through the integration of many IoT devices, components, and sensors to generate, store, and analyze the data. This involves a continuous adjustment and dynamic improvement on the energy management system, while constantly improving the shortages and drawbacks resulted from the transition of the conventional method to the adoption of Big Data into the system.

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