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Monitoring System for Residential Energy Consumption

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ABSTRACT

The aim of the present paper is the management of the energy-consumption of a residential building, where the addressed case is to figure out the trends of reducing energy consumption through many aspects like intelligent decisions making which is mainly based on good informed management. A leaky bucket problem is an analogous case to the proposed vision of the energy consumption, where it is essential to know the whole image of the leaky bucket contains some leaking openings and their corresponding locations and sizes before starting to close the leaks. Consequently, it is a mandatory phase to learn the energy-consumption system of a building before implementing any decision to modify or to improve the energy system under consideration. Concisely, the main objective of the proposal is to process to control the operation the consumption of energy for a residential system by considering real-time basis. Therefore by providing an information about electricity based on real-time at different levels for the utilization and consumption is the main goal of such control. To have a visual and right image of energy consumption that is undergoes in a building, a monitoring operation can give an excellent feedback. A framework to control the energy consumption as well as the smart management is adopted to achieve this goal.

KEYWORDS

Energy consumption, green building, monitoring; management, big data.

1 INTRODUCTION

Basically, there are many interpretations and meanings that the word "green" may imply. This term can refer to a range of meanings starting from preserving and protecting the originally nature and ended to switch off the illumination sources before departing the building, and in particular from the political catchphrases to the everyday habits of the individual, where assessing the potential of energy efficiency in the building is a very important intuitive to develop the energy policies [1], especially since the consumption of energy in big commercial buildings is considerably higher than in elsewhere sectors [2]. Therefore is so important and substantial to understand the links between global stability and the green energy-based sustainability through focusing on the main role of green energy to achieve global stability and sustainable development [3]. On the other hand, studying the status of electricity consumption for the main appliances and equipment, the energy efficiency progress, and estimates of the electricity-saving potential in residential sector is a great of interest as well [4]. The idea involves a lot of ideas and actions to be eventually green, environmental or even sustainable, like using recycled material, solar and wind energy [5], [6]. Mainly, towards saving natural resources of the earth and minimizing global warming, the efficiency of the energy consumption is one of the significant thoughts particularly through reducing fossil fuels burning. The energy consumption over the years if could be traced back, it might be illustrated that residential buildings are the main cause (International Energy Agency IEA) is exceeding the 40% of the world's energy consumption [7]. Growing of population and economy in the world, it is obvious that constructing buildings will continue. Therefore, the challenging query is by any mean to make or to adapt them to be as an efficiently energy? Numerous implementations can be done to achieve this task. One of these activities also can be designing green building [8]

that keep back energy due to well thermal insulation to manage between energy saving means. Studying and to improve efficiency, sustainability and reliability of the energy production, consumption and distribution have been carried out by many works. Generally, two parallel scenarios are considered in the energy domain to achieve efficiency. First, the supply side is under focus by the researchers, where the contributed thoughts were mainly concerned with introducing renewable energy sources such as wind, water and solar. These contributions were concluded by proposal of Amin and Wollenberg [9], where the management technology of the supply-side is named as smart grid. Digital processing and communication can be applied to improve sustainability as well as efficiency of the distribution and the production of energy [10]. Many researchers have demonstrated a joint vision of the future for the American electric delivery system smart Grid which is named as Gird 2030. The main goal of the second path, was to minimize the part of the demand-energy consumption, where it has been investigated by many researchers. Demand-Side Management DSM has been referred since the 1970s, where started to be implemented by US energy utilities for reducing the residential as well as demand through of the commercial electricity and numerous energy conservation trends. These trends can be information distribution programs, free installation subventions of further conserving technologies and equipment [11], [12], [13], [14], [15], [16], [17]. Basically, it is well known that at the beginning of the 1990's, formally the green-building movement has begun, which is intensely been driven by the effective use of many resources like energy and water and many others [18]. As aforementioned, the main part of the energy consumption of the world is the buildings and mostly up to 70% in few countries, like UAE based on the Middle East Centre for Sustainable Development. Numerous investigations regarding this issue has been discussed in the literature survey. In general, there are two scenarios mainly making the building more energy efficient. The first task is focused on how technique to design building to conserve energy, and secondly is thepart similar to the DSM programs, by the fact of focusing on the activities inside a building on how to manage and to operate the energy utilization [19], [20], [21]. An internationally accepted benchmark for high performance constructions (i.e., green buildings) is established by the U.S. Green Building Council (USGBC), which becomes a third-party certification program for the design, construction and operation, Leadership in Energy and Environmental Design (LEED) [22]. Actually, to focus on the design concepts of the building and not on the management of the energy consumption is the framework certification of the LEED program. Although LEED shows covering the management portion, it requires to be adapted to track and estimate of the real energy consumption in the considered buildings. As a matter of fact, the LEED tends to be more building-design frame rather than being energy consumption management, according to our classification of research contributions in energy efficiency at the level of building demand-side. However, to establish an evaluation process that evaluate and assess the influence of the design and operation practices on the real energy consumption in occupied buildings are considered as a genuine suggestion headed for LEED certification.

Our proposed software is a framework that gathers a pool of smart techniques that operate together in order to endorse energy efficiency through smart monitoring the real energy consumption and energy massive data analytics. As a result, an ongoing education toward energy conservation for the building occupants will be established. This contribution is an implementation of the suggested proposal to the LEED program. A rapid evolution in the monitoring and the analysis the energy utilization of the buildings with the purpose to control and decrease energy costs is highly observed, which is basically is the field of building energy management. By collecting data at hourly or any intervals via using automated meter reading approaches, can generate a large collection of data that requires analysis. Automated processing of this data can be done through using computer analysis through using machine learning techniques, invoking professional analysis where variances are detected. In general, machine learning continuously needs a

historic dataset to practice models and for establishing a benchmark for describing what founds an anomaly. Building performance simulation used by computer analysis uses physical concepts to guess energy performance, and permits the expectations of the activities of buildings from a pure simulation background. Through an image to the production of artificial bespoke benchmarks where historical outlines are not presented, [23] explored how building modelling approaches can be fused into energy management training. A real accommodation was monitored to collect and to estimate the precision of the method. It was revealed that machine learning from simulation models could have a high internal accuracy compared with the real metering data, which illustrated predictable errors in the system close to 20%, but attained a considerable improvement over industry benchmark values. Douglas [24] explained the main features that dynamic data-driven application systems (DDDAS), where A DDDAS is an application that has data assimilation that can modify the models and/or scales of the computation and that the application steers the data collection based on the computational results. He described what a dynamic big-data-driven application system (DBDDAS) toolkit necessity to have in order to deliver all of the substantial building blocks that are required to simply produce new DDDAS without re-creating the building blocks. A substantial efforts have been done by the City of Stockholm towards meeting its climate change commitments including a GHG emission target of 3 tonnes per capita by 2020 and making its new eco-district Stockholm Royal Seaport a candidate of Clinton Climate Initiative's Climate Positive Program.

Towards achieving these policies, [25] Shahrokni et al. evaluated the energy efficiency potential in the city, in collaboration with the district heating and electricity utility Fortum. A new understanding of energy use in the city emerged through drawing on their massive billing meter data on the housing stock in the city. The retrofitting potential of the building stock to current building codes can minimize heating energy used by one third. This revealed through analysis done of the energy efficiency potential of different building vintages.

It has been clearly evidence that big data has drawn massive attention from investigators in information sciences, policy and decision makers in governments and enterprises. However, the huge volume of data contains much potential and highly useful values hidden. A new scientific paradigm is born as data-intensive scientific discovery (DISD), also known as big data problems. On the one hand, Big Data is extremely valuable to produce productivity in businesses and evolutionary breakthroughs in scientific disciplines, which give us a lot of prospects to make great progresses in many fields, like energy monitoring and conservation. On the other hand, Big Data also arises with several challenges, such as complications in data capture, data storage, data examination and data visualization. Philip Chen and Zhang [26] demonstrated a view about big data, including big data applications, opportunities and challenges, as well as the state-of-the-art techniques and technologies we currently adopt to deal with the big data problems. It is also discussed several underlying approaches to handle the data deluge. Data management is being recognized as a significant bottleneck, regardless of whether data is stored in a cluster, grid, or cloud. Computing elements can be located far away from the data storage elements. One of the biggest issues in data intensive computing is the energy efficiency of the data centres storing this data. In order to report such matters, Vrbsky et al. [27] designed and analysed a series of energy efficient data aware strategies involving data replication and CPU scheduling. It was introduced a new approach for data repetition, named Queued Least-Frequently-Used (QLFU).and studying its performance to determine if it is an energy efficient approach. Moreover, studying the advantages of using a data aware CPU scheduling approach, named data backfilling, which uses job pre-emption in order to take full advantage of CPU usage and enables for longer periods of suspension time to save energy. The performance of QLFU was evaluated and existing replica strategies on a small green cluster to study the running time and power consumption of the strategies with and without data backfilling.

Outcomes from this investigation validated that energy efficient data management can shrink energy consumption without negatively affecting the response time. What is named U-Eco City, is a development and research project established by the government Korea [28]. Basically, the objective of the project was to monitor and to visualize of combined and real time states of numerous energy consumption habits that represented by location based sensor data accumulated from city to building scale. A platform's middleware was established into an advanced prototype and operative providing information to a Web-based client that interfaces and integrates with the Google Earth and Google Maps plug-ins for geospatially referenced energy utilization conception and monitoring. Large data was accumulated in all aspects. In general, thee advances in the technology of the sensors, wireless communication, internet and low-cost memory have mainly contributed to an bang of the big data. However, System of Systems (SoS) integrates independently operating, non-homogeneous systems to reach a higher task than the sum of the parts. At the present time, SoS is likewise contributing to the being of unmanageable big data. In recent times, efforts have settled a promising method, called "data analytics", which assumes statistical in addition to computational intelligence tools like as principal component analysis, clustering, fuzzy logic, neuro-computing, evolutionary computation Bayesian networks to decrease the size of "big data" to a controllable bulk, these tools can be used to information and form a knowledge base using the derived data, to develop a non-parametric model for the big data. Tannahill and Jamshidi [29] illustrated how to develop a connection between SoS and Data Analytics to establish consistent models for such systems. The aim is to use data statistics to develop a model to forecast made photovoltaic energy to help in the optimization of a micro grid SoS. through using tools like neural networks, fuzzy interference, PCA, and genetic algorithms. Big-data analytics is one of the most important applications of upcoming generation parallel and distributed systems . Data repositories for such applications currently go beyond exabytes and are speedily growing in scope. Beyond their sheer magnitude, these datasets and associated applications' considerations pose significant challenges for technique and software development. The size and privacy considerations of the distributed datasets is warrant distributed techniques. Usually with extensively changeable computational and network experiences, data often resides on platforms. Considerations of fault-tolerance, security, and access control are critical in numerous applications [30]. Analysis tasks often have hard deadlines, and data quality is a main concern in yet other applications. Basically, data-driven models and methods, capable of operating at scale, are unknown for most emerging applications. The validation of results is a major issue, even when known methods can be scaled. Characteristics of hardware platforms and the software stack fundamentally influence data analytics. Kambatla et al. [31] focused on the emerging trends to highlight the hardware, software, and application landscape of big-data analytics.

2 PROBLEM DISCRIPTION

As a matter of fact to address energy conservation is considered challenging and impressive. Basically, this issue becomes more interesting when relates its consequences to the human actions. Positive habits like turning off the illumination sources and the screen of the computer before departing the room is considered completely a human behavior. So establishing continuous education and competitions headed for preserving energy is the main task in this proposal. Helping building occupants toward conserving energy is the other consequent challenges which highlight the usage of the real-time program engineering and the interaction of the human computer. The following points can summarize the subsequent challenges:

(1) At dissimilar level of the building as well as at different time scales, a system to monitor the usage of energy is required.

(2) It is needed to establish a sensing and metering operations to acquire the energy utilization information at multi-level of the building. As a consequence, to establish the

infrastructure of the network to transfer the metered energy measures is included.
(3) To be sure that the communication between different instrumentations and installations, protocols are required.
(4) The energy consumption database (the historical data) must be developed and managed to represent the energy data.
(5) Automatic sensing and metering can generate which can be served to acquire energy outlines and most best practices in the direction of cost-effective energy management.

3 THE PROPOSED SYSTEM

Basically to give the aforementioned problems and challenges, the solution for energy conservation is strongly associated to the success in establishing an continuous education and competition among residents of the building in the direction of the energy saving. We proceed by two steps, in order to have a concrete solution. The first one consists in planning an architecture that groups the big image of the suggested solution. The goal of the first step to propose a framework for the management of the energy consumption that will be elucidated in the present paper. Though, the second stage consist of in establishing a high fidelity prototype that implements the adopted procedure on a certain building, the college of information technology building in the UAE University. The next stage is the goal of the instant upcoming work.
In the direction of an architectural design of the proposed scenario, the following points are accomplished. This is what can be considered as functional requirements of the energy framework.

4 REQUIREMENTS OF THE ENERGY FRAME WORK AND BIG DATA ANALYTICS

(1) Studying the installations and apparatus in the buildings with the most high consumption. The objectives and indicators of the energy conservation will be determined . Later on, it will be decided the granularity of metering and sub-metering. In the college, as an example, it can be metered the consumption at different levels.

(2) To determine the specification of the system (i.e., smart metering/sensing), as well as its scale and composition. At this stage, it will allow to speculate the essential equipment, like sensors and meters besides to the network infrastructure to communicate with the instruments.

(3) To design a database to save energy utilization data appropriate to the building structure and satisfying the energy management goals. This data base will be used to design the best energy consumption practices.

(4) Designing and developing a dashboard for visualizing the information of the energy consumption. This software application is going to offer a user friendly tool and customizable graphic charts user interface that enables the building residence to monitor the energy utilization at every specific time interval. Mainly that means monitoring at multi timescales and interest shapes the energy consumption. User outlines contain, simple occupant, lab technician, equipment maintenance agent, building manager, etc.

(5) To develop different protocols to seize and transfer energy data to the energy utilization database and to the monitoring dashboard. Eventual communication between sensors/meters will be responsible by these protocols.

(6) Supporting to make decision in the direction of energy preservation, design and developing a software tool is required. Data gained from the energy utilization database and study models of best practices will be used as inputs for this tool. These models are then will be adopted to gain the smarter measures to reduce energy consumption.

(7) Establishing the unit measuring of every system, which includes dashboard tool, network communication infrastructure, protocols, decision making support tool and energy database system. It is highly recommended to be sure that each individual system is well examined at this level of the proposed solution plan.

(8) Adopting integration to testing numerous systems in the building environment. This must include an integration of the dashboard, energy consumption database and the metering-sensing system, whereas a second integration will examine the decision making supporting tool and energy consumption database.

5 FRAME WORK STRUCTURE

The requirement and the analysis elicitation guided us the following architectural modules of the proposed framework:

Software monitoring application: It is real-time engineering tool that provides a spectrum of interpretations and illustrations that will send feedback to the user on instantaneous energy consumptions activities in the building. It is mainly a dashboard that observes a combination of nominated energy utilization gauges finally selected by the users .

Metering and sensing system: A metering and sensing system will be installed in the building which enables to acquire energy measures at numerous levels (e.g., having meters at cafeteria laboratory, office, classroom, etc.). This system is going to contain a communication protocols and network infrastructure.

Decision making and control system: This tool is a the second stage software that will analyze occasionally or per user need, the gathered data and signal abnormal energy utilization of the particular instrumentations or location. Infrequent utilization can be signed when becomes more than the expected consumption allocated, as an example, through the equipment technical specification. Furthermore, this useful tool will supports to take decisions to change activities, or to tune or upgrades installation.

Database of the energy consumption: The present database is critical to evaluate the building attitude and building occupants behaviors concerning the energy utilization. It will clearly show the influence of the best consumptions and taken readings to promote energy preservation. Besides, the collected information can be a appreciated input to train energy cost approximation model and to guess the energy needs. This can be done through adopting a novel model methods [32].

Educational component based on social media: This module is going to be responsible to share, publish and to discuss energy utilization and consumption issue as well as culture. It goals at launching a culture and education of energy saving among building occupants. Moreover, this element will test tweets and posts from social networks in order to collect energy data and learn negative and positive energy utilization patterns.

The big image of the proposed framework is illustrated in Figure 1. The major outline components and the relationship between them, can be caught in particular.

Without any negative concerns, the potential of application of this proposed framework is clearly visible. It can be applicable to a wide range of companies and firms, installations building, etc. In order to validate the framework and finally to develop it, it is proposed to establish an framework that consists of dashboard software application to monitor energy utilization of buildings in the university campus, as a model of the exist governmental buildings and installations. Moreover, the system can include even a wireless monitoring and control system for the gardens [33] to optimize water and energy consumption, since the region has big temperature difference between the seasons.

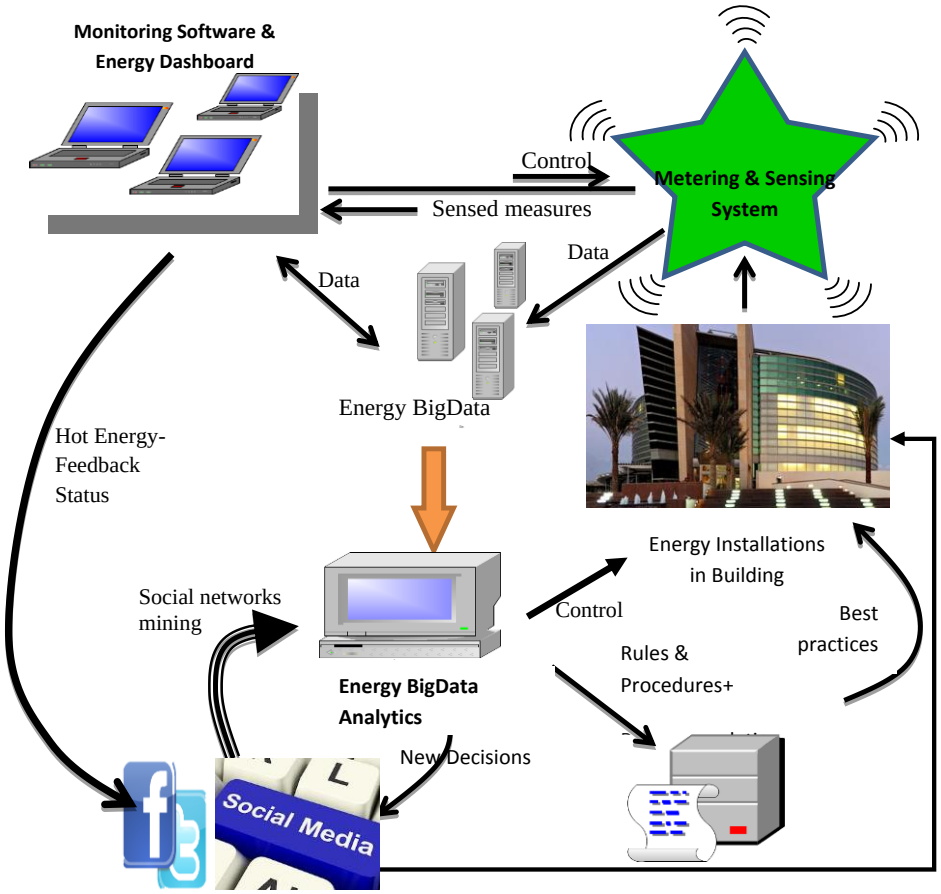

Figure 1. The proposed frame work.

6 CONCLUSIONS

One of the universal and crucial concern of our life if the energy conservation, since it is related directly the humanity. It remains a hot subject due to its several dimensions of the treated problem, although, it has been targeted by many researches and governments around the world from different aspects , renewable resources, supply-side, building construction area, demand-side , building occupants activities, etc.. Various trends and techniques can be used to bring support to energy utilization and consumption. In this work, Our main contribution to assist improving energy conservation via introducing a software based tools. Since it is initiated on the fact that energy preservation is connected to the behavior of the building occupants, therefore this challenge is extremely significant. We believe that it is a crucial and successful project to use the proposed framework scheme in order to report, inform,

avert or advice people. This is because it gives feedback and answers the residents enquiries and assists them to minimize their energy consumption. In general, The occupant is going to develop a self-evaluation process by being informed, and eventually a behavior modification toward energy conservation. This can be targeted by the proposed research challenge through the ongoing education. Implementing different software components will be the future work of the proposed energy management framework. Besides, framework customizations to different building specifications will be included as well.

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