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A Review: Buildings Energy Savings - Lighting Systems Performance

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ABSTRACT Lighting systems are one of the highest energy consumptions specifically in buildings. Thus, by designing energy efficient systems, it would contribute much to buildings energy savings. Therefore, this paper motivation is to review a number of lighting systems designs applied to many types of buildings. It is then so important to discover what methods and systems which have been proposed to save energy in buildings in term of lighting. By finding out what proposed systems are for different types of buildings, designers and respective researchers e.g., buildings engineers would find possibility and applicability of such lighting systems for certain types of buildings to achieve higher energy savings than some other systems when applied to the same types of buildings. Such a relation between reviewed lighting systems with types of buildings would be helpful for many researchers from different fields. There exist numerous factors that play an important role in achieving higher energy savings rate on which efficient energy lighting systems rely. This paper aims to review several types of lighting systems designs applied to different types of buildings. Additionally, performance(s) of lighting systems might vary depending on the design of the lighting system to achieve higher buildings' energy savings. In this review paper, several past studies that utilized Information and Communication Technology (ICT) from the perspective of energy Informatics for a smart lighting system that efficiently achieves energy savings have been considered. This paper has considered different types of lighting systems and types of buildings. Cited papers in this review paper are derived from six digital libraries which are: IEEE Xplore Digital Library, ScienceDirect, MDPI, Emerald Insight, ACM DL, and Taylor & Francis Online.

INDEX TERMS Lighting systems, buildings energy savings, daylight systems, occupancy-based lighting systems, large scale buildings, sky view factor, rural buildings, ICT for energy informatics.

I. INTRODUCTION

Lighting plays a vital role in energy consumption due to many considerations. One of these is that the lighting affects other energy consumption sources. Hence, the lighting performance has an impact on those sources and therefore it is needed to be addressed by relevant research studies. A research study reviewed in [1] has mentioned that accurate estimation of energy consumed caused by lighting in a building has to take into account the interaction of lighting with other consumers e.g., Heating, ventilation, and air conditioning (HVAC). Effective lighting management leads to a better energy savings rate for many types of buildings and using different types of systems.

Usually, there are many strategies applied to lighting systems (LSs) designs in buildings in order to achieve a high level of energy savings. In literature, several reviewed papers have introduced three different strategies used by LSs for energy savings. Occupant profiles based, timers based, and daylight variations based LSs are widely implemented by energy management systems for Building Energy Efficiency (BEE) achievement [2]. There have been varied methods and systems designed, implemented, and applied on different types of buildings using different scenarios to verify the

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energy efficiency in term of lighting systems design. Some proposed methods have focused on occupants' comfort, some others have focused on intelligent lighting, and some others focused on scheduling management of LSs and so on.

There is a relation between lighting systems and type of buildings when some factors are considered. For example, one of these factors is that, the large scale building is better to have more efficient lighting systems such as daylighting systems or other energy efficient systems. Also, for large scale buildings, it is advisable to use either light management systems or natural lighting to achieve higher energy savings. The type of building can be considered as another factor if the lighting system will have affected the energy use. For example, for rural buildings, the better lighting system is, the more energy efficient is. Other than these, to find the best lighting system for a certain building, there is a need to perform an appropriate evaluation method to come up with the best design [3]. Also, some types of buildings, e.g., rural, would be utilizing natural or daylights to overcome cost of installation if a retrofitting strategy has been applied.

This review paper has considered several types of buildings e.g., residential [4]–[9], commercial [5], [10]–[14], large scale [15], and rural [16]. It has also considered different types of systems designed to achieve energy savings in regard to lighting. Some examples of energy savings utilized lighting systems reviewed in this paper are daylight [17]–[25], occupancy [26], [27], retrofitting [28], and time scheduling-based energy-efficient lighting systems [29]–[31].

Besides, in literature, there are many systems which consider sky surrounding the building reviewed. For example, in [32], the sky view factor has been studied in order to find the relation between the visible area of sky and surroundings, e.g., buildings. Another research is reviewed in [33] has considered the effect of adjacent shading caused by sky surrounding on buildings. This factor has an effect on the building's energy-use and achieved energy savings.

All in all, proposed systems reviewed in this paper fall in one of two techniques utilizing light either by artificial systems or as daylight [34]. Artificially designed systems will be more adequate with intelligent, smart, residential and commercial buildings while daylight-based systems could be exploited by rural buildings more than by modern ones to balance cost of retrofitting and the equipment installation.

This review paper is organized as follows: In Section II, Research Questions are highlighted. In Section III, the Method applied for reviewed papers' collection procedure is explained. A detailed Literature Review on past studies related to LSs for energy savings in buildings is provided in Section IV. In Section V, current and future issues related to contribution of Information and Technology Communication (ICT)-based LSs to energy informatics have been discussed. In Section VI, the trends in lighting systems for buildings' energy saving are highlighted. Section VII provides a summary of selected reviewed papers considering a number of factors and features. Discussion and Conclusions are drawn in Section VIII.

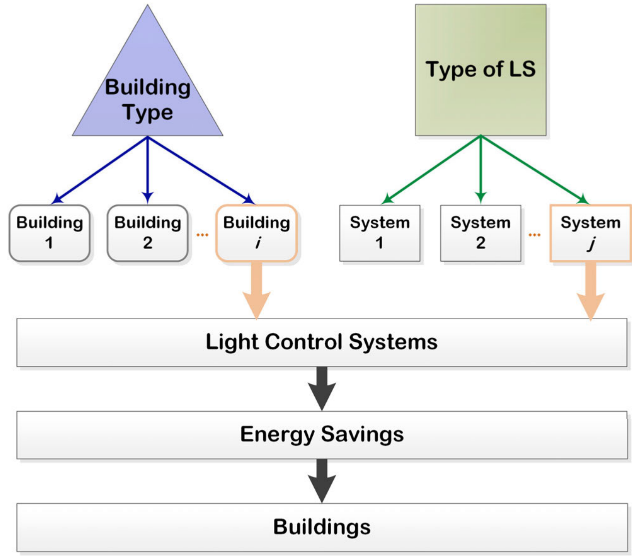

FIGURE 1. The proposed method for keywords extraction.

II. RESEARCH QUESTIONS

RQ1: What are types of light systems designed and proposed for energy savings?

RQ2: What are types of buildings for which light systems have been designed?

III. METHOD

A. PROBLEM STATEMENT DEFINITION

Energy savings in buildings varies depending on the system designed. There are different systems used for this purpose. One of these systems is the lighting systems (LSs) used for energy savings in buildings. Different types of LSs have been applied to different types of buildings. This paper aims to review numerous LSs and also to compose a group of similar systems designed for a certain type of buildings.

Meaning: the relationship between Building types and System types is of type "many-to-many":

$$\infty \; Bulidings\ types \rightarrow LSs\ types$$

B. PROPOSED METHOD FOR KEYWORDS EXTRACTION

Mainly, methods and/or strategies previously proposed to concern the lighting systems management which have been applied on several kinds of buildings aiming to achieve energy savings as high as can. The proposed process applied to extract general keywords can be graphically depicted in Figure 1.

C. THE PROPOSED METHOD FOR KEYWORD SELECTION

As discussed above, there are different buildings' types for which many types of LSs have been designed. This review paper has selected most known buildings' types used as real scenarios when such a system is implemented, as can be seen in Figure 2. This paper has only considered LSs therefore

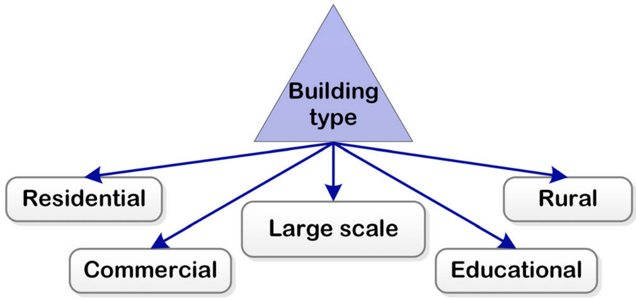

FIGURE 2. Keywords Selection Process for Buildings' Types.

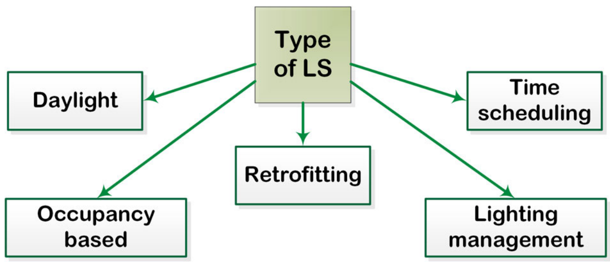

FIGURE 3. Keywords Selection Process for Types of LSs.

TABLE 1. Keywords extraction using two fields "Title" and "Abstract" of a paper.

Title of paper	Operator	Abstract
"light systems"	AND	"energy savings"
"lighting retrofit"	AND	"rural buildings'
"time schedule-based system"	AND; OR	"light energy savings"

selected types of LSs in term of lighting will be depicted in Figure 3.

D. MULTI-KEYWORD-BASED PAPERS COLLECTION MECHANISM

By using the proposed flow-diagram process in Figure 1, a number of keywords can be extracted. For instance, "*light systems*", "*building energy savings*", "*light systems for large scale buildings*", "*lighting retrofit systems*", "sky surrounding a building". However, depending on the digital library used to search for the related paper, the keyword is able to be modified in order to give a more accurate result. In Table 1, further examples of keywords are provided to clarify how the related paper is extracted using a clearer keyword.

E. PAPERS' SELECTION PROCESS FROM DIGITAL LIBRARIES

There have been six digital libraries amongst others chosen from which cited papers in this review have been taken. The corresponding journals and conferences' proceedings are only those indexed by SCOPUS and/ or WOS. Another condition has been taken is that published papers within the period from 1999 to 2019 thru which twenty-year have been published and indexed by SCOPUS/WOS are cited. Further information related to the proposed papers' collection method is provided in Table 2.

TABLE 2. Digital libraries -related selection process conditions.

Digital library	IEEE Xplore Digital Library, ScienceDirect, MDPI, Emerald Insight, ACM DL, Taylor & Francis Online
Publisher	IEEE, Elsevier, MDPI, Emerald, ACM, Taylor & Francis
Publication date	Paper published between 1999 and 2019
Indexed by	"SCOPUS" OR "WOS"
Further criteria	Limitation= "light control system" AND "buildings energy savings"

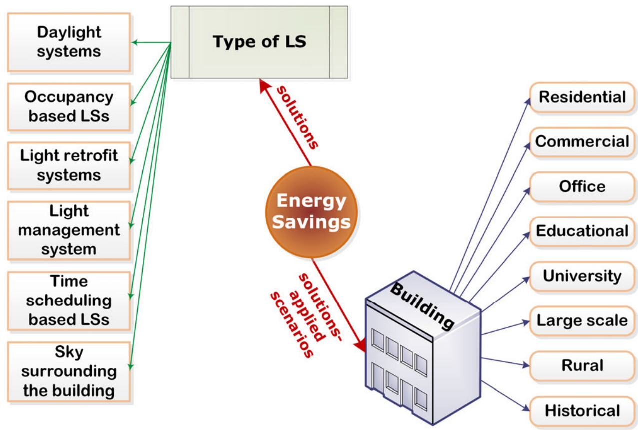

FIGURE 4. Proposed Method for Objectives' Relationship with Solutions.

F. THE PROPOSED METHOD FOR OBJECTIVES' RELATIONSHIP WITH SOLUTIONS

By tracking designed systems and proposed solutions to achieve a goal of "energy savings", there will be several real scenarios "buildings" for which systems have been designed. There exists a relationship between solutions and buildings and this paper attempts to finds out this type of relationship and how suitable it is to use a certain system for potential types of buildings to reach a high level of the goal. Meaning, "*how suitable and efficient is a system used with a certain type of buildings to achieve a high level of energy savings?*" This is simply graphically depicted in Fig. 4.

In this figure, the proposed method attempts to obtain the strength of efficiency for a solution, i.e., a system, to reach the "energy savings" goal for a certain type of buildings.

G. THE PROPOSED METHOD FOR ENERGY INFORMATICS RELATED KEYWORDS EXTRACTION

This subsection briefly presents the proposed method designed to extract keywords related to Energy Informatics. It has been applied on reviewed papers in order to have them classified into conventional and smart LSs. Those reviewed papers that have fulfilled the following criterion: a selected reviewed paper that has adopted ICT to design such an

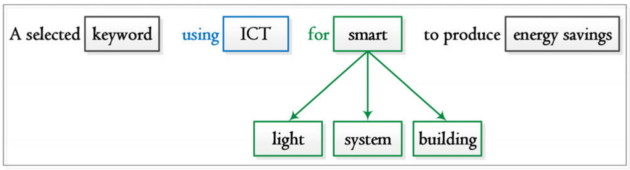

FIGURE 5. A graphical representation of energy informatics and its keywords.

intelligent light system or *adaptive LSs* for *smart management* or a *smart building* to achieve *energy savings* to contribute to *Energy Informatics*, is classified as an ICT-based LS for energy informatics.

Based, there will be a number of keywords, for example, *intelligent light system*, *adaptive LSs*, *smart management*, *smart building*, and *energy savings*. Therefore, if a paper contains more than two keywords, that paper is classified as an *energy informatics* related paper. This is simply how a keyword related to an *energy informatics* paper is extracted. This is depicted in Figure 5.

IV. LITERATURE REVIEW

It provides a review on several lighting systems designs applied to several types of buildings implemented in many countries different conditions have been considered. These factors have been one of the main reasons to produce varied energy savings rate(s). These have been discussed in and reviewed. Main types of lightings systems which have been reviewed are: daylight, occupancy-based, lighting retrofit, and time scheduling lighting systems. In the following subsections, they are in detail reviewed.

A. DAYLIGHT SYSTEMS

1) DAYLIGHT SYSTEMS APPLIED TO RESIDENTIAL AND COMMERCIAL BUILDINGS

A research work presented in [4] has aimed to control the lighting system in commercial and educational buildings. It has considered daylights to achieve much efficiency in terms of energy demand caused by lights. The proposed method applies a measurement tool to acquire data using sensors installed inside rooms. Then, it implements a detailed analysis procedure applied on the daylight in order to verify energy savings gained from the proposed LS strategy. The analysis output is used in order to derive a correlation between indoor and outdoor illuminance changes and that is mathematically formulated in an equation. This equation will be then used for future prediction and estimation of energy-use. During analysis and evaluation, the proposed LS will apply this proposed methodology in order to control lightings inside the building and can calculate the rate of energy savings and the Building Energy Efficiency (BEE). The proposed method has been applied on a university building. Experiments have been tested in regard to daylights and Building Automation and Control Systems (BACS). The proposed method has reduced the energy-use in non-residential buildings in terms of lighting. Thus, it has achieved 28 % and 24 % of BEE for offices and educational buildings, respectively, as reported in the paper.

Similarly, in regard to proposed systems applied to commercial buildings, a recent daylight system has been proposed [35]. It then aimed to discover the relation between daylight systems for artificial light and energy consumption achievement in a hall inside a commercial building. The proposed work has considered a number of variables that affect the performance of LS e.g., outdoor light, windows material, light deflector, and zonal lighting control. Then, the authors have applied a computer-based simulator to estimate energy need, so that, the proposed work could contribute to the BEE and energy savings performance(s) of the hall being tested. Results of the proposed work [35] have confirmed a total of 2.2 % and 17.6 % of energy reduction achieved from a single zone and multi-zone lighting controls, respectively.

2) DAYLIGHT SYSTEMS APPLIED TO RURAL BUILDINGS

A simple definition can be: rural areas or buildings located in rural areas are considered by this type. Also, historical buildings are included in this type. Thus, related reviewed papers in regard to these types of the building will be presented within this category thru this paper sections.

There are varied types of buildings in a rural area e.g., residential buildings and schools. The energy demand by those buildings varies and thus it is necessary to design a system in which daylight is efficiently utilized. Such a design will be so useful for buildings which mainly depend on natural lightings. Researchers from different areas have tried to design various systems to utilize as much as possible to gain a larger amount of daylight (i.e., lux) so that a lot of energy consumption for a smarter building can be reduced using an intelligent lighting technology. As for example, the researchers in [36] have implemented a study in South Africa and they have designed a good technology to utilize daylighting by using zenithal light pipes. The good feature in using the zenithal light pipe technology is that it can involve supportive materials which obviously contribute much in enhancing performance of the zenithal light pipe's basic design. In [36], the design has exploited a light collimator to distribute the daylight inside the pipe in a parallel way so that the lux could be increased. As stated by the researchers, the room illuminance has been increased from 179 to 370 lux during day-time. To achieve a better illuminance rate in term of stable distribution of lights inside the pipe by the collimator, a special material has been used to cover inner parts of the collimator to evenly distribute an increased amount of daylights.

3) DAYLIGHT SYSTEMS APPLIED TO LARGE SCALE BUILDINGS

Large scale buildings include different types of buildings that fulfill a special criterion. They might be, as defined in [37], neighbors of residential buildings or a group of academic buildings e.g., a university. It, however, might include a complex mall that is considered large. In addition, a building in which its area is larger than a normal residential building e.g., a certain commercial building.

Some techniques applied to large-scale buildings are reviewed. One of the issues affecting daylighting performance in term of visual quality and energy savings is that the way the external shading is designed. There are many proposed systems presented different kinds of solutions. In [18], several factors have been examined if they can contribute in energy savings rate. A case study implemented in Greece has mentioned that wall insulation as a building envelope installation under certain conditions can enhance energy savings and reduce energy consumptions too. In this setting, a proposed system [38] has mentioned that when an increment of 5 cm to 7 cm to wall insulation design can reduce energy consumptions by about 5.58 %. Such a system can be efficiently exploited by large scale buildings to increase energy savings rate.

To study the effect of shading technique in term of light energy savings in large scale buildings, a recently proposed system reviewed in [39] has applied a shading designed system with a modified configuration made specifically to enhance energy demand by the selected building when this technique has enabled to use less energy by lighting and cooling units inside the building. It has been mentioned that the proposed design [39] using self-shading and envelope shading has saved 20.5 % of examined energy consumptions. In addition, its payback was confirmed to be two years whereas this period has been enhanced when it is compared to [40]; its expected payback is within about 3.9 – 4.9 years. Similarly to the proposed study [39], a shading system has been introduced in [41] in order to achieve high energy savings with the enhancement of daylights admitted to the building. It has mentioned that a larger size of a glaze allows more daylighting to transmit. As for large scale buildings, large glazing is needed to achieve higher sun-light with a reasonable energy savings. This study has been implemented on a large scale building; a university campus in Egypt. With an artificial lighting system, energy savings and visual quality for indoor spaces have been enhanced. In [39], [41], case studies have been performed in hot regions during summer season. Another case study implemented in cold regions [42] to utilize sun-shading for a better daylighting design has focused on the external shading. The aim is to study the effect of sun-light using a shading design on internal indoor lights as well as energy savings. Results reported have enhanced lighting inside the building with visual comfort.

B. OCCUPANCY BASED LIGHT CONTROL SYSTEMS

Occupancy based lighting control systems play an important role in energy savings, specifically in room buildings and offices because they efficiently analyze sensors-derived data of occupants' daily activities.

In this type, usually, the occupant needs to be detected by sensors. Assigned sensors will detect variations either in motion, sound level, or temperature. The sensor is installed in a circuit placed on most suitable locations inside the building. It is advisable that occupancy based LSs use wall-mounted sensors. Wall-mounted sensors are reported to save energy and cost as well as easy-to-wiring to nearer electrical switches. Once the motion of occupant(s) has been detected, the controller circuit will turn lights on or off.

In regard to commercial buildings, a recently reviewed system in [43] has considered individual occupants in an office building. There are various factors and settings that significantly and directly interfere with the performance of occupancy based LSs applied to room office buildings. For example, there are differences between individual occupancy patterns based and varied occupancy patterns based. In this settings, the research study proposed in [43] has stated that individual occupancy patterns based lighting control systems do not significantly contribute to energy savings due to differences between a desk and room control are minimal. Therefore, the study in [43] has investigated the influence of occupancy pattern variance on energy savings gained by occupancy based strategy. This control strategy has then been implemented in different zones in an office space building. This study has chosen three different zone-based settings to measure each zone's energy savings. Results have shown that variation in occupancy patterns can produce a different percentage in energy savings. The proposed study [43] has suggested using occupancy-based LS at the desk level setting in office buildings. Meaning, variations in occupancy patterns have produced different performance percentages in energy savings. Related results have reported that energy savings gained from an individual light control (e.g., in case of an individual can adaptively dim light during lunch hour) are more when a room-control or a subgroup controlling strategy is adopted. Energy savings obtained from individual occupancy based has been on top amongst others e.g., subgroup and room control. Similarly, the energy-use measurement has been found, it is the lowest when the individual occupancy control setting is used. The energy savings percentage from an individual occupancy-based LS was between 25 % and 30 %, which is better compared to manually controlled systems.

C. LIGHTING RETROFIT SYSTEMS (LRS)

Lighting Retrofit Systems (LRSs) applied to buildings are used in an extensive way aiming to energy savings. Once an LRS has been applied to such a building, it is usually followed by a number of necessary verification steps to make sure that lighting upgrade has fulfilled an acceptable level of energy savings, cost, quality of lighting conditions and occupant comfort [44]. A practical study implemented in Malaysia on residential sectors has aimed to measure energy savings and emission reduction of lighting retrofit [45]. This research study has performed an analysis based on cost effectiveness. The obtained results have found that retrofitting of lighting-efficient systems would contribute to energy savings for many residential buildings.

1) LRS FOR RESIDENTIAL AND COMMERCIAL BUILDINGS

LRS applied for residential and commercial buildings has used different designs and approaches during implementation. In addition, applied designs have used different types of lighting systems e.g., light-emitting diodes (LEDs) specifically those lighting devices which have more energy savings when comparing to others. Some designs and retrofitting techniques have installed lighting devices in stairways, roofs, and corridors areas in order to come up with a higher energy savings rate depending on the current scenario being studied.

In [46], an LRS has been applied and implemented to an educational building in Italy. The proposed system has performed an evaluation and comparative analysis amongst different types of lighting devices in order to measure the best ones that contribute much more to energy savings to the selected building in terms of energy use and cost. The research work has selected the optimal solution for energy efficient device based on an analytical comparison.

2) LRS FOR RURAL BUILDINGS

A study has mentioned that rural buildings in China consume a large amount of energy compared to cities [47]. Different strategies have been applied to control the light use by rural buildings. One of these examples is to design a standardized limit for a rural building in order to control the light energy use [48]. In China, a limit value of lighting energy density equals to 7 W/m^2 has been set for each rural residential building [48] at a specific area. Some other designed systems e.g., [49] have set a value of 2.5 W/m^2 as a lighting energy limit value for a rural building.

Another example has proved that LSs can achieve a higher energy savings percentage with the help of lighting retrofit. The paper presented in [50] has considered a number of strategies to be applied on a rural building. One of these strategies is to replace currently used fluorescent light elements with LED ones. Such a retrofit of conventional lighting systems is applied due to the main aim of energy savings to a good level (30 % when it is measured amongst other previous factors' rates $\sim$ 60 % when it is measured amongst its previous rate) as well as occupants' comfort. The proposed system has installed new lighting elements replacing existing fluorescent lights by LEDs in order to enhance the light illuminance and save more energy with preserving indoor comfort. By applying this system to a rural building in Italy, it has contributed to the overall light energy reduction by about 60 %. This system is considered effective for buildings equipped with a large number of conventional lights.

In [51], to contribute to energy savings in rural buildings, it is advisable to retrofit the currently existing buildings. This would efficiently enhance buildings energy savings, as this has been applied in the UK.

One more example reviewed in [52] has been applied in a rural area in China mentioning that once incandescent light bulbs have been replaced by compact fluorescent light bulbs (CFLs), it is expected to achieve of about 27 % of energy savings. It has stated that replacing bedroom lights with CFLs, a further lighting energy savings rate can be gained as well as CO_2 emission.

3) LRS FOR LARGE SCALE BUILDINGS

There are a number of systems which encourage designers of energy-related sectors to apply retrofit approaches to large scale buildings [53], [54].

Usually, in large scale buildings, there exist numerous supportive strategies to lighting retrofit in order to achieve highly measured rates in energy-use levels. Several past studies have counted various examples of case studies which encourage to use a mix of strategies along together with lighting retrofit strategy [55].

D. LIGHTING MANAGEMENT SYSTEM

Lighting management contributes to balance between energy consumption reduction and occupants' comfort in terms of visual quality [56]. Lighting management is a very considerable issue when designing a smart lighting system for buildings. In addition, effective implementation of lighting management produces efficient data processing for smart building systems [7]. Thus, lighting management has focused on improving different types of lighting units such lamps, luminaires, LED, and lighting controls [57].

There are numerous LSs which have achieved an acceptable level of energy savings and some others have not. Such a management approach dedicated to those LSs with low energy savings would be beneficial and applicable. In literature, there is an example of a lighting management system that has enhanced the energy savings gained from LED lighting. The designed management system [58] has enhanced LED lighting in terms of waste heat caused by incremental cooling needs resulted from the LED overall performance. The proposed lighting management system has proposed an exchanger module that efficiently moves the LED emitting heat to outdoor. So, as a result, this management module has enhanced energy savings with the occupant comfort that doesn't require further lighting control action such as turning off lights at intervals of time.

E. TIME SCHEDULING BASED LSs

A programmable controller is usually used to turn-on and turn-off lights at pre-defined intervals of times. Some proposed systems have mentioned that about 35 % of energy reduction can be achieved e.g., [59].

The proposed method in [31] has focused on how to reduce energy consumptions by applying a time-based scheduling LS. The proposed system has utilized daily routines of occupants' activities. Firstly, these daily activities are recorded. Then, data is collected and ordered in regard to the Five Ws Questions (in this study, Six Ws consisting of 5W and 1H have been used). After that, occupants' activities i.e., Six Ws-retrieved data is analyzed to set the best occupants' comfort option. This paper has considered five procedures in order to enhance the provided scheduling LSs, which are: house

TABLE 3. A summary of selected reviewed papers with consideration of a number of factors and features.

Ref.	Aim of paper	Type of LS	Type of Buildings	Strengths	Weaknesses	Method applied	Location
[4]	To address the energy demand caused by lights.	Daylight systems	residential & commercial	- Lighting can be controlled. - Energy Saving = 28%.	-	It uses a measurement tool to acquire data using sensors.	-
[35]	To discover the relation between daylight systems for artificial light and energy consumption achievement.	Daylight systems	commercial	- It contributes to the BEE and energy savings performance(s). - 17.6 % of energy reduction achieved from multi-zone lighting.	2.2 % of energy reduction achieved from a single zone	It has used a computer-based simulator to estimate energy need.	-
[36]	To reduce much energy consumption using an intelligent lighting technology.	Daylight systems	rural	The room illuminance has been increased 2.1 times.	- Cost - Requires several materials	It has designed a light collimator to distribute the daylight inside the pipe in a parallel way to increase the lux.	South Africa
[38]	To consider the wall insulation under certain conditions to enhance energy savings.	Daylight systems	large scale	It can increase energy savings rate.	-	It has adopted 7 cm to wall insulation design.	Greece
[39]	To study the effect of shading technique in term of light energy savings	Daylight systems	large scale	- The method uses less energy by lighting and cooling units. - 20.5 % of examined energy consumption. - Its payback is 2 years.	-	It designed a shading system with a modified configuration made specifically to enhance energy demand.	-
[41]	To study that a larger size of a glaze allows more daylighting to transmit	Daylight systems	large scale	- With an artificial lighting system, energy savings and visual quality for indoor spaces have been enhanced.	-	Several models are used to produce electricity and provide shading to the building utilizing Integrated Photovoltaics attached on its window. Photovoltaics act as multifunctional elements.	Egypt
[43]	To consider factors affecting individual occupants	Occupancy based light control systems	commercial & office	- Energy savings can be achieved from individual occupancy based is better than from groups'. - Energy saving is up to 30%.	- Not suitable for room LS or sub-group LS.	It investigated the influence of occupancy pattern variance on energy savings gained by occupancy-based strategy.	-
[45]	To measure energy savings, emission reduction of lighting retrofit	Lighting retrofit systems	residential	- Retrofitting of lighting-efficient systems contributes to energy saving for many residential buildings.	-	It performed an analysis based on cost effectiveness.	Malaysia
[46]	To measure the best lighting devices that contribute to energy savings.	Lighting retrofit systems	residential, commercial & educational	- Suitable for optimization solutions.	-	It performed an evaluation and a comparative analysis amongst different types of lighting devices.	Italy
[48]	To control the light use by rural buildings.	Lighting retrofit systems	rural	- Suitable for pre-defined energy use limit for certain areas.	-	It designed a standardized limit for a rural building in order to control the light energy use.	China
[50]	To replace currently used fluorescent light elements with LED	Lighting retrofit systems	rural	- Energy saving varies between 30 and 60%.	-	It installed new lighting elements replacing existing fluorescent lights by LEDs in	Italy
	ones.					order to enhance the light illuminance.	
[51]	To contribute to energy savings in rural buildings	Lighting retrofit systems	rural	- energy savings is enhanced.	-	It is advisable to retrofit the currently existing buildings.	UK
[52]	To achieve more energy savings by applying a retrofitting of specific light devices.	Lighting retrofit systems	rural	- Energy saving achieved is about 27%.	-	It replaced bedroom lights with compact fluorescent light bulbs (CFLs).	China

TABLE 3. *(Continued.)* **A summary of selected reviewed papers with consideration of a number of factors and features.**

[58]	To enhance the energy savings gained from a LED lighting by utilizing lighting management systems	Lighting management system	office	- Energy saving is enhanced.	- It works effectively under certain conditions, e.g., when the occupant doesn't require further lighting control action such as turning-off lights at intervals of time.	It proposed a lighting management system using an exchanger module that efficiently moves the LED emitting heat to outdoor.	-
[31]	To reduce energy consumptions by applying a time-based scheduling LS	Time scheduling based LSs	occupancy	- Many factors are considered. - It meets smart home requirements. - Energy consumption reduced. - Energy demand reduction is 19.2%.	-	It has utilized daily routines of occupants' activities.	-

environments, service determined, similarity analysis, data filtering, and smart service. It has also allowed occupants to develop the proposed system in order to meet smart home requirements. This feature has significantly contributed to reducing energy consumptions by customizing one-on-one service that enables occupants experience to modify operations by which energy savings can be achieved. While the proposed scheduling LS has adopted a Six Ws- retrieved data, it usually produces a huge volume of redundant data which cause a huge load when the system is running.

F. SKY SURROUNDING THE BUILDINGS

There is an effect on the use of lighting inside the building due to the daylight factor and sky view surrounding. Studies reviewed in literature have shown that such a clear sky view would have a significant factor on the use of lighting in a building and also on the overall energy consumption [60]. As for example, in [61], the research study has mentioned that the surrounding factors would be contributing to energy savings once these factors are effectively designed and used. In [60], for example, a daylight factor is considered and verified either the energy saving can be achieved or not. The study has tested this factor under the condition of a clear sky view surrounding the building (thru a window). The study confirmed that the sky conditions surrounding the building has an impact on enhancing illuminance thru windows and that therefore has achieved the energy saving rate. The energy saving reported in [61] utilizing the sky surrounding factor approximately equals to 4.5%. A proposed study reviewed in [62] has reported that the clear sky condition will contribute energy use and more energy saving rate could be achieved. It has mentioned that when the sky surrounding has a cloudy view, the energy use is getting higher. Another study reviewed in [63] has stated that the sky view surrounding the buildings, with the help of other factors, can significantly help enhance the daylight design and achieve a better energy efficiency rate in related buildings [64].

V. ICT-BASED LS CONTRIBUTION TO ENERGY INFORMATICS – CURRENT AND FUTURE ISSUES

In this review paper, a number of past studies have designed an ICT-based LS to achieve a high "energy savings" rate and some others have applied non-ICT related LSs. Thus, there are two types of systems in which "energy savings" is being measured and evaluated one of which has contributed to Energy Informatics. Therefore, some LSs require ICT to process information whereas some others do not.

The reviewed papers here have contained both types of LSs either those utilizing ICT to achieve Energy Informatics in the purpose of "energy savings" or not. In regard to ICT-based LSs, there have been a number of systems focusing on improving "buildings energy savings" using smart systems. Those systems, even though, which have achieved in energy savings and contributed to Energy Informatics either by using smart sensors or smart processes, Artificial Intelligence is an example, are still facing several challenges. Amongst these, the number of systems with a high level of energy savings rate is considered of limitation. However, there are some smart systems applied to concentrate on light management, adaptively smart light systems, or time schedule based light systems for smart scenarios have proved they are energy efficient systems.

In future, ICT-based LS related studies need to be extensively concentrating on achieving Energy Informatics purposes and objectives for a high "energy savings" for "smart buildings" using "smart systems".

VI. THE TRENDS IN LIGHTING SYSTEMS FOR BUILDINGS' ENERGY SAVING

Nowadays, there are two significant challenges related to trends in lighting systems associated with deferent types of buildings which are the production of energy efficient lighting systems and reduction of lighting costs. In this setting, the connected lighting systems might contribute to achieving either one of them or both probably. The connected lighting system will be depending on the programmable system to, for example, turn-off lights with timely basis, utilizing time scheduling based LSs. This is one example that can be addressed by researchers to overcome such challenges.

Another example is to use LED replacement devices utilizing retrofitting systems. to achieve higher energy saving rates, further enhancement(s) need to be considered currently used

TABLE 4. Current problems faced by numerous systems.

Lighting system	Current problem(s)
Daylight systems applied to residential and commercial buildings	For a single zone 2.2 % (low energy savings) compared to multi-zones is still not that high of energy savings rate.
Daylight systems applied to rural buildings	The energy demand by those buildings varies and sometimes is high.
Daylight systems applied to large scale buildings	The way the external shading is designed is still affecting the daylighting performance.
Occupancy based light control systems	Some factors and settings that affect the occupancy based LSs to office buildings might be the differences between individual occupancy patterns based and varied occupancy patterns based.
LRS for residential and commercial buildings	A lot of lighting devices are installed inside the building roofs and corridors.
LRS for rural buildings	Rural buildings in some countries consume a large amount of energy compared to cities.
Lighting management system	Related lighting management systems require efficient data processing for smart building systems.
Time scheduling based LSs	Daily activities are recorded. Then, data is collected and ordered

TABLE 5. Future directions.

Lighting system	Future direction(s)
Daylight systems applied to residential and commercial buildings	Proposed systems still need to be improved to consider a number of variables e.g., outdoor light, windows material, light deflector, and zonal lighting control, in order to achieve higher energy savings.
Daylight systems applied to rural buildings	It is necessary to design a system in which daylight is efficiently utilized.
Daylight systems applied to large scale buildings	Designs are encouraged to consider a larger size of a glaze allows more daylighting to be transmitted.
Lighting retrofit systems	- There is a need to go for using natural lighting to reduce the cost caused by retrofitting systems. - Researchers from different areas have tried to design various systems to utilize as much as possible to gain a larger amount of daylight (i.e., lux) by enhancing inner parts of pipes (collimator) and enhancing materials which distribute daylights to a building, specifically large-scale buildings. - It is advisable to use compact fluorescent light bulbs (CFLs) to achieve more 27% of energy savings compared to incandescent light bulbs.
Lighting management system	One of the enhancement(s) for future works for the currently proposed lighting management systems is to efficiently use an exchanger module, or any other technique, that efficiently moves the LED emitting heat to outdoor.

systems and techniques and/ or proposing new retrofitting systems that can be efficient and cost-effective.

Other trends can be the effective use of management systems such as to control every room's lights individually to control the energy consumption.

A research study has mentioned that one of the most effective trends in lighting systems related to buildings energy saving is that one which contributes to both energy saving and sustainability [65]. The indoor lighting plays an essential role in energy savings and occupants' comfort. The most important in indoor lighting is to come up with such a technique that contributes to the optimization of energy conversion utilizing many types of lighting devices e.g., incandescent bulbs, modern LEDs, organic LED (OLED), and lighting induction lamps techniques.

Another trend in lighting systems for buildings energy savings can be discussed in [66]. The study has mentioned that retrofitting strategies of energy efficient lighting systems can be considered as the most effective techniques. As for this trend, the study presented in [66] has come up with these retrofitting options. For example, it is better to utilize the most energy efficient lighting devices (e.g., lamps), exploit daylighting systems, use light colored walls and ceilings.

VII. A SUMMARY OF SELECTED REVIEWED PAPERS WITH CONSIDERATION OF A NUMBER OF FACTORS AND FEATURES

In this section, many reviewed papers are summarized in Table 3 to include several factors and features. Topics which have been included in Table 3 are: aim of the reviewed paper, type of lighting system, type of buildings for which a LS is used, strengths, weaknesses, method applied, and location the study is implemented in, respectively.

VIII. DISCUSSION AND CONCLUSIONS

Conclusions are discussed in four parts, which are as follows: A detailed summary about findings out, the suitability of current lighting systems to different types of buildings, current problems faced by proposed systems, future directions in this field.

A. A DETAILED SUMMARY ABOUT FINDINGS OUT

This paper has attempted to review numerous research studies related to lighting systems (LSs) applied to buildings either those LSs are implemented to real scenarios or just simulation-based approaches. The main aim of this review paper is to collect different types of LSs related research studies applied to different types of buildings that contribute to energy savings. Thus, the purpose is to highlight performance(s) of different LSs designed and implemented to various types of buildings e.g., residential, rural, and large-scale buildings.

Several criteria have been applied for the selection process of cited papers from digital libraries. For example, published papers from 1999 to 2019 have been selected. Only six digital libraries have been used for papers cited in this paper which are as follows: IEEE Xplore Digital Library, ScienceDirect, MDPI, Emerald Insight, ACM DL and Taylor & Francis Online.

Reviewed research studies have reported different levels of lighting systems related performances and thus different levels of energy savings have been achieved depending on two correlative impacts which are: the LS design and type of building. Meaning, when a LS is designed for a specific type of building, the LS's performance might achieve a high level of energy savings rate compared to the same LS when it is applied to another building. The reason is that, outer conditions with each building might vary and surely has a direct effect on the performance of LS being used with.

B. SUITABILITY OF CURRENT LIGHTING SYSTEMS TO DIFFERENT TYPES OF BUILDINGS

Lighting systems' performances are discussed to mention suitability of lighting systems on different types of buildings.

1) For example, daylight systems could be suitable for buildings which have an extensive view to receive a lot of natural lights. This condition might be compatible with large scale buildings. In addition, performances of daylight systems also can be better when some supportive external conditions such as sunny environment not cloudy area at most of the times, are abundant and considered by LS designers.
2) In regard to occupancy based LSs, it is recommended in order to achieve higher energy savings and enhance LS's performance, to be applied to offices and those buildings in which lights are evenly distributed and spaces are occupied orderly in terms of lighting. Otherwise, a time scheduling LS will be an alternative solution and strategy for such a case.
3) There are some research studies which have discussed an important issue related to rural buildings, ancient buildings, or those which are located in rural areas, that is a simple LED replacement technique might be a good solution instead of implementing an extensive retrofit strategy that might be costly and inefficient in terms of energy savings, energy management of resources, or energy efficiency. Similarly, those buildings in which the cost of retrofitting is increased and the energy savings performance is reduced caused by many conditions, might be suitable to apply the lighting retrofitting systems to.
4) Lighting systems management has become a key strategy applied by smart energy management systems and smart home applications. Additionally, lighting systems management has contributed to enhancing the performance of other lighting systems such as lighting retrofitting systems in terms of energy savings and waste heat emission.
5) In regard to smart LSs which have utilized ICT towards energy informatics, they have been discussed to highlight current and future issues and directions aiming to produce more efficient LSs in terms of energy savings to enhance smart buildings conception and other related smart fields.
6) Another factor that affects the energy use within a building is the sky view surrounding the building. Reviewed papers have mentioned that the clear sky view surrounding would contribute much to the reduction of the energy consumption and also to energy savings. Similarly, some reviewed studies have confirmed that the cloudy sky conditions will affect in lighting-related use and therefore energy consumption will be higher than the clear sky surrounding conditions.

C. CURRENT PROBLEMS FACED BY PROPOSED SYSTEMS

Current problems which are derived from several existing proposed systems are summarized in Table 4.

D. FUTURE DIRECTIONS

Future directions in this field are provided in Table 5.

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