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Energy Efficiency in Smart Buildings: IoT Approaches

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ABSTRACT The Internet of Energy (IoE) impacts on smart cities' power sector. IoE is an implementation of the Internet of Things technology (IoT) into distributed energy systems and aims to achieve energy efficiency, to avoid energy wasting, and improve environmental conditions. IoE technology includes, among others, utilizing smart sensors and renewable energy integration. Therefore, the IoE is becoming a legal science tool to serve the purpose of a smart city. In this paper, we refer to the reasons that led the European Union to compile Regulations for facilitating transformation of existing cities, starting from existing buildings, into smart buildings. We propose a smart building template that manages the performance of all technical systems through IoT technology with the view of achieving energy efficiency. In addition, in order to improve the certification of existing buildings, as for energy performance, we propose an automated remote, control method supported by cloud interface. This method minimizes time consuming procedures and stores, on a cloud platform the energy performance of each building, for the purpose of drawing conclusion and applying measures.

INDEX TERMS Energy efficiency, energy performance of existing buildings, Internet of Things, smart building template, smart energy management.

I. INTRODUCTION

In a smart city, technology is placed in the serve of society in order to achieve the smart objectives of every living factor that motivates society, such as the administration, citizens and industry. This way prosperity of the city is ensured. Energy is the driving force of a city and the energy saving is a major issue for the whole world. The use of alternative energy sources, the reduction of gas emissions, the contribution of the Internet of Things (IoT) technology to monitor energy consumption and control energy performance is of vital importance.

To meet the objectives of a smart city and energy efficiency, not only the reconstruction of new smart buildings and the transformation of existing buildings into Nearly Zero Energy Buildings (NZEB) is crucial, but also the transparency of Energy Performance Certificates should be improved. According to the European Commission's impact assessment, provisions concerning the inspections of Energy Performance Systems were found to be inefficient, because they could not guarantee the initial and continued performance of a building's technical systems. The Energy Performance Certificates should ensure that the performance of installed, replaced or upgraded technical building systems are documented and all necessary parameters for measuring energy consumption are checked, as well as, all the requirements for minimum energy performance are stated. The adaption of the IoT technology in building certification and compliance checking could facilitate inspections.

The European Union acting in this direction and willing to ensure Europe's energy security, competitiveness and sustainability, proposes a gradual implementation plan of the smart cities institution in its Member States. These solutions are structured in conjunction with IoT technologies. According to European Legislation [1], the European Union indicates to the Member States to fulfill the Union's target of reducing its greenhouse gas emissions by 30% below 2005 levels, in 2030 (an initial period from 2021 to 2030) and this contribution of each Member State will be evaluated annually.

According to Directive 2018/844/EU [2], the European Union indicates the need to decarbonise ''its building stock'' considering that almost 50% of Union's final energy consumption is used for heating and cooling, of which 80% is used in buildings. The Union's goal is to follow renovation

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TABLE 1. Proposals for existing and new buildings according to 2018/844/EU[2].

Proposals	Proposals
Focus on:	Improve:
Eggshell	Insulation
Heating	Thermal Comfort
Domestic Hot Water	Functionality
Cooling	Thermal comfort
Lightening	Visual comfort
Ventilation	Healthy conditions inside

strategies that give priority to energy efficiency and renewable sources of energy in order to transform the existing buildings into NZEB. In this direction the European Union forces all Member States to propose actions [2] so as to accomplish the Union's purpose, underlying that these actions should focus on technical systems that reduce the energy needs in a building, improve environmental conditions inside the building and energy performance, as well, see Table 1.

Furthermore, the European Commission in order to measure energy savings, apply benchmarking and realize the flexibility of turning into NZEB processes, shall adopt a delegated act by 31/1/2019, by establishing a common Union indicator for rating [2] the Smart Readiness of buildings, see Table 2. This indicator applies in all Renovation Strategies of Member States, in order to conclude the progress for each Member State as for the transformation into smart city, see Table 3.

TABLE 2. Establish the definition of the smart readiness indicator [2].

	The Smart Readiness Indicator	
measures	enhanced functionality	energy performance
uses	information, communication technologies	electronic systems
points out the needs of	the occupants	the grid
indicates the value of	building automation	electronic monitoring
achieves	energy efficiency	confidence to occupants about saving

According to the 2019 Assessment of Second Long-term Renovation Strategies [3] under the Energy Efficiency Directive (EED) [4], about the strategies that were submitted

TABLE 3. To calculate the smart readiness indicator [2].

	The Building Systems through interconnected and intelligent devices should	
maintain	energy performance	operations of the Building
adapt	energy consumption through energy efficient sources (e.g. renewable sources)	dynamic and interchangea ble Operation mode
achieve	user friendliness	healthy indoor climate conditions
report	energy use	electricity demand
enable	intervention on grid demand	grid's Proper distribution

TABLE 4. The 2019 assessment for compatibility with EED for the renovation strategies proposed in 2017 [3].

Best Renovation Strategies 2017	Precentage of compliance with EED
France	84%
Spain	84%
Belgium Wallonia	80%
Croatia	80%
Czech Republic	80%
Greece	80%
Sweden	80%
Cyprus	76%

in 2017 from 30 Member States, 27 strategies out of 30 were considered fully or almost fully compliant to EED, as for energy efficiency and renovation of the existing buildings and 3 strategies were considered as noncompliant, see Table 4.

It seems of great importance the collaboration of the following factors in the direction of securing future's environmental conditions: The guidelines that are provided in the EED, the proposals of each European contracting State to implement those directives which will ensure a better life, as for quality and sustainability, to European citizens and the grant of efficient Building Certificates, as for energy performance. The IoE which is an implementation of the IoT into distributed energy systems can contribute in this direction, applying IoT tools such as cloud technology and Wireless Sensor Networks (WSNs). These sensing devices which are wirelessly connected can communicate with each other and with the Internet [5], can conduct measurements and collect data from all building's technical systems remotely and automatically. Then, this information can be stored in a database using cloud technology and will be accessible to the authorities in order to monitor the energy consumption of the building, to observe possible energy wasting, to draw conclusions about energy performance and check the negative or positive impact of each building to the indicator of Smart Readiness. Consequently, solutions can be proposed in order to improve energy efficiency of the building that is inspected. The result of this procedure is that all buildings will gradually be able to transform into NZEB with consistently in the timeline.

Contrary to fragmented and unverified as for compatibility with European legislation technological proposals in the literature, which they might not all be feasible and applicable in reality for smart cities, due to legislation, in this paper our contribution is that we present a research based on European legislation and therefore the legality of applying our technology proposals to smart cities. This research for the compatibility of the proposed technology with European legislation has not been carried out in other technology proposals, so far. We try to develop a smart technology building template according to the legal frame mentioned above, choosing from a technological background, technologies feasible and in accordance with the law. This smart technology building template will be a sensor-based architecture that supports the operation of energy consuming technical systems. This whole smart building will be controlled by a smart management system with the aim to achieve energy efficiency.

In addition, for existing buildings, regarding the Smart Readiness indicator and bearing in mind the aim of European legislation for the gradual transformation of buildings into smart buildings, which has not been considered in literature before, and furthermore with the view to improve Building Certification and compliance checking of existing buildings as for energy performance, we try to develop a management system which will check the energy consumption of a building's technical systems remotely and will propose solutions in case of energy inefficiency. In this way the instantaneous presence of an inspector in a building which reflects instantaneous and approximate measurements of technical systems, with the possibility of a major error, could be replaced with remote and continuous measurements under various conditions, which is not regarded in the literature. All mentioned above will be developed considering European standards, the legal framework introduced by the European Union for smart cities and with a view to improve well-being in European societies.

This paper is going to follow a qualitative and bibliographic methodology in order to list actions for the problem of energy wasting. The rest of the paper is organized as follows; In Section 2 there is a review of the related research on smart solutions for Smart Buildings that use smart technology and IoT solutions, in order to achieve energy efficiency. Section 3 proposes a smart technology template for a building in terms of smart technology and energy efficiency. Section 4 discusses an optimally way for monitoring energy consumption in existing buildings. This could be a remote and automated approach for the supervision of a building and for reducing the energy consumption that stems from its operation. Moreover, in this section proposals are stated for controlling energy losses in existing buildings. Last but not least, Section 5 provides the conclusions of the current paper and Section 6 proposes new possibilities for the development of future work.

II. RELATED WORK

For the purpose of this study we review and analyze previous literature which has been published in the field of smart buildings, energy efficiency and IoT technology, in order to collect all representative technologies regarding Heat, Ventilation, Air Condition systems (HVAC), Renewable Energy systems (RES), Building Energy Management Systems (BEMS) and generally energy efficient methods applicable to smart buildings. The methodology we follow utilizes European certification, European legislation and literature in order to propose a smart building template for new buildings and a management system for checking all technical systems in existing buildings in order to contribute to the gradually transforming of existing buildings into smart buildings and to the remotely Building Certification as for energy performance in existing buildings.

The following paragraphs present the papers which contributed significantly in our study. To begin with the eggshell of a smart building, an optimized thermally control storage, using phase change materials (PCM) integrated to walls, is presented in [6]. The problem of the shift between energy production and heating energy demand is solved by using isolated PCM panels inside the building walls and a heating system that uses a pumped hot water circuit to load the PCM plates. The heat stored in the PCM is achieved due to the increase of heat exchange surface by PCM's low thermal conductivity and its incorporation into microcapsules, and due to the heat return which is controlled by forced transfer. The PCM plates are separated from the wall insulation by an air layer which allow ventilation on request from all wall's surface in order to extract the heat stored in the PCM.

By using sensors the temperature of the room and the temperature of the PCM plates can be monitored and through weather forecast the temperature of the outside air is disclosed, so as to check the effectiveness of the system. It ensures 10-15% energy savings, quick heat distribution on request and therefore comfort for the users inside the building.

In [7] is proposed the use of thermal images to detect insulation problems of the eggshell of a building. This method identifies temperature variance in a building with thermal images of segments of the building. Higher variation of temperature is proven to mean poor insulation or damages in the wall surfaces. A FLIROne camera and an android Smartphone was used to collect 50 thermal images from inside and outside of the building that cover moisture problems, insulation problems, thermal bridging, electric outlet holes. The researchers identify insulation problems with 75% accuracy.

In [8] it is stated that the durability of the material used in a building's walls, such as concrete can be monitored through IoT real time sensors. These sensors transmit data like humidity, wirelessly to a mobile application but have limited lifetime. Therefore a low cost, screen printed, resistivity sensor is presented that has the ability to be implanted in concrete during the construction of a building and collect real time measurements for a lifetime. These measurements concern the moisture degree of concrete which is vital for a structure in order to ensure durability. This sensor implements preventative monitoring which is vital for a building's structure.

In [9], an Indoor Air Quality low cost and energy efficient sensor that is easy to operate, is presented. The IAQ sensor is monitoring the indoor air and report in a smart device the existence of PM2.5, CO2, CO and O3.This sensor will notify to the occupants of a building, the absence of fresh indoor air in order to take measures. This is a matter of health and will contribute in building ventilation, in reducing gas emissions and only by monitoring continuously the indoor air quality.

In [10] is stated that occupancy and occupant behavior in a building impacts on energy efficiency, due to the use of Heat, Ventilation, air condition, lightening and other electric devices by occupants. Therefore, a building occupancy prediction model is introduced that gives 90% accuracy and uses 8 sensors to collect data every 20min, or 5 sensors to collect data every 15min. Building data that are used refer to indoor temperatures, humidity, Co2 level, windows and door state, outdoor temperatures and humidity and they are obtained from different sensors that exist inside and outside the building and they are associated with building occupancy.

In [11] is stated that smart solutions and IoT can help to predict a sudden burst of a fire by monitoring and quick reacting. The described system includes an internet connection for communication and control between fire alarm pull, fast-response and slow-response sprinklers, fire bell, a local security operator and air exchange module. Sensors on sprinklers monitor fluid consumption. A smart device can be used to monitor the whole system, so the security staff can receive alarms and notifications, all the time. Based on IoT communication, in case of a fire, the air exchange system is activated, the fire bell starts to ring, the sprinkles are activated, the whole procedure is monitored and the people in charge are informed about the emergency.

In [12], the SAFETY Project is presented for fire prevention in buildings. This project is an environmental monitoring system and operates 24hours every day. Its implementation is based on an IoT system used for monitoring and controlling several environmental parameters through custom smart boxes installed in each room of the building. The system uses an efficient software platform that is cloud based in order to handle requests from many devices. It also manages and monitors every element of the infrastructure. The Smart Box which is an intelligent device of the system is able to manage several environmental sensors connected to it. 6 environmental sensors tests humidity, temperature, carbon monoxide, smoke presence (PIR sensor), and identifies a building set on fire. The system sends data to cloud to be stored, processed and analyzed and is monitored through a mobile application.

To continue with the indoor conditions in a building we searched for lightening technology. In [13] a lightening design is implemented using temperature and light intensity which ensures increasing of power efficiency up to 82.77% at a day time and minimizes carbon emissions by cancelling the use of florescent devices and static power control. The proposed design uses LEDs and sensors that sense the surrounding light and temperature and then control power dynamically. When the environmental light intensity increases, the power supply decreases dynamically in time.

A connected indoor lightening system is presented in [14] with embedded sensing, control and networking technologies that optimize lighting operations. This system connects sensors, luminaries, controllers and gateways using the internet. Luminaries with sensors stated on the roof are easy to maintain, and provide high spatial resolution of data. These data ensures lighting optimization and improvement in operations. The system consists of an application programming interface (API) that enables users to control lighting system settings and a data API for monitoring the system and the lighting data.

Focusing on the interior conditions of the building, we continue with automated heat supply management which is referred in [15], which optimizes with accuracy the temperature of a building. This method based on IoT platform, ensures reduce in costs and comfortable temperature for the occupants. The system through sensors that are located inside and outside the building, gathers information,(temperature, weather, wind, pressure), in real time and through 3 layers it produces the heat map of the building and builds a digital twin of the building by analyzing all streaming data collected from sensors.

To continue with renewable energy sources that can be used in a building in order to reduce gas emissions and power consuming, Solar Energy Photovoltaic (PV) system allows to store solar power in batteries, for using when the power grid goes down [16]. There is also the Grid Connected PV System which is a solar electricity system without batteries and these are the simplest systems and the most cost-effective to install in a building.

In [17] is presented a Photovoltaic (PV) generator which is connected with storage units and supplies the electrical loads and the thermal demand in order to turn into electrical by using heat pumps. The system purpose is to maximize the self-sufficiency and to minimize the use of the grid. Sensors are applied in the rooms of the building so as to monitor the energy exchange between them. The authors say that an energy simulation must perform on a yearly basis in order to evaluate the size of the batteries and the costs and they state that a future purpose of this system is to achieve yearly self-sufficiency instead of seven months per year (April to October).

In [18] a real time NZEB prototype is developed using wireless sensors to achieve home automation with IoT. NZEB concept, which includes the use of renewable energy (like solar), intelligent controllers configured with Arduino UNO and IoT technology like sensors (light sensor and temperature sensor) and also a mobile application, ensures that the net energy consumed from the utility grid over a period of time (monthly/annually) will close to zero because the net energy is the difference of the energy imported from grid, to the energy exported to grid over a period of time. So, the sensors will measure the room illumination and temperature levels and send the measurements to cloud in order to control the electrical demand.

In [19] a model which is proposed for energy efficiency by using the Fuzzy Control System, achieves to reduce the water flow rate without disturbing the comfort of the occupants of the building. This model is suitable for buildings with central heating system and uses artificial intelligence technology in every room. The benefit that this method offers is that with smart rooms and intelligent control, the unused rooms are not supplied with hot water and therefore heat calories are distributed more effectively and energy efficiency is achieved.

In [20] a smart hot water control system is presented which is performed automatically based on IoT data. This means that the control of the hot water heating system adapts the heating times to the data collected of the user's behavior and this leads to energy savings. The models that are developed are based on Gaussian processes and neural networks and are supposed to compute optimized heating schedules that lead to significant energy savings (saves between 20 and 34% of the energy used with a default schedule) for all users over a testing period of six months.

In [21] the presented prototype allows remote monitoring of electricity consumption in a home, based on a web application, using the XBee technology, which allows the implementation of a wireless sensor network with energy efficiency and low consumption, and a protocol for data communication. It is a real-time system which collects data by areas to check the variation of consumption in each room with 1-minute time intervals and the results are stored in a database in the cloud. The XBee operates as a coordinator in the system and collects data from 4 Mmod sensors, that sense the current consumed by the electrical appliances and the supply voltage and transmits it to the client PC, so it can send it to the cloud. This web application notices unnecessary electrical consumption, minimizes waste of energy, and relocates the demand of electricity.

An IoT-based smart system able to control the Air Conditioning in order to produce a thermally comfortable indoor environment by monitoring air temperature and humidity inside a room is presented in [22]. The system will interact with the user by inserting his/her thermal feeling from -1 to $+1$. Together with sensors' data, the information will be integrated with a Predicted Mean Vote (PMV)-based algorithm to the cloud server so that the occupant can feel thermal comfort by controlling smartly the AC. According to [22], the system has three input variables which are users' feeling or user PMV preference (-1 to $+1$), humidity (from 40% to 90%) and room temperature (from 19°C to 34°C) and two output variables which are temperature of the AC (from 17°C to 26°C) and fan speed (from 0.1m/s to 0.5m/s). Lastly Arduino software is used to program the system.

A building management system that achieves the reduction of energy consumption and optimization of the lighting and HVAC (Heat Ventilation Air Conditioning) control is presented in [23]. Passive infrared sensors are proposed to predict the presence of occupants in each room. Temperature and humidity sensors adjust the lighting, air cooling and humidity in a room. An acceleration sensor monitors doors and windows in case a window glass is broken or a window is opened in a non-occupant room. Through light sensor and for the purpose of reducing the electricity consumption, the lights automatically are switched off when the rooms are unoccupied. This real time, cost effective and automated system can be configured using a web interface to control the actuator nodes which control HVAC and lighting systems in the building, dehumidifiers, air coolers and security alarms. Lastly, cloud computing is responsible for storing the data, analyze and develop actions, and visualize the data to ensure efficient management of the building.

The method proposed in [24] is low cost and implemented as an application on Building Energy Management System (BEMS). It uses IoT technologies and ''a plug & play'' learning framework to automatically identify the thermal model of each thermal zone in a building. This thermal model is using a learning framework with low-resolution temperature readings from IoT-based smart thermostats connected to the cloud. Given the indoor temperature gradient prediction model, the indoor temperature can be forecasted using an algorithm. One of the inputs is the operating schedule of AC units and the output is the indoor temperature profile under such operating schedule.

A multi-HVAC system which consists of a set of HVAC subsystems (heat pumps, chillers, cooling towers or boilers) is presented in [25]. The proposal is adaptable to multi-HVAC or single-HVAC systems, both centralized and distributed. This approach does not need to invest in changing the existing HVAC installations or redesigning the building. The multi-HVAC system consists of HVAC subsystems for heating or cooling generation. ACODAT is used for the management of building's multi-HVAC systems by noticing the optimal operation that maximizes energy savings with the highest possible indoor comfort. It adapts the multi-HVAC system to accomplish this optimal operation with the BMS (that analyze the data sensed from the environment in order to obtain the optimal operational mode in a given moment) and control modules (to control the active HVAC subsystems).

The first module explores different combinations of HVAC sub-systems and selects the best one for the current conditions. The second module then translates the decision made to the control and BMS modules. ACODAT management controls, forecasts, plans, organizes and improves the energy consumption, the indoor comfort and the equipment performance.

A novel distributed Model Predictive Control (MPC) proposal is presented in [26] that reduces energy consumption and billing costs and ensures comfort to the occupants of the building. The described model uses a heat pump connected to thermal energy storage, a consumer unit (e.g. a building) and renewable energy sources. The authors consider a subsystem composed of two components: the thermal storage coupled with heat pump and the electrical grid coupled with PV panels and heat pump. The usage of a Thermal Energy Storage (TES) gives the chance to satisfy demand in an economic way by storing energy in thermal terms during off peak hours. The solution uses predictive controllers that exchange data in order to optimize the energy spent. One MPC satisfies indoor comfort in a way that the thermal storage temperature follows the predicted inlet temperature demanded by the room and the other MPC makes economic control decisions to optimize the cost of keeping the TES at the requested temperature that satisfies indoor comfort. The results show that the goal is achieved by 37% cost saving and 15% load energy saving.

Table 5 lists the findings and the concepts examined in each paper about smart solutions for smart buildings that use smart technology and IoT solutions, in order to achieve energy efficiency. The papers are described through the published year, the authors and the problems and solutions that they deal with.

III. A SMART TECHNOLOGY BUILDING TEMPLATE

In this Section a proposal is developed of a smart technology template for a building in terms of technology and energy efficiency. The proposed template, see Fig. 1, is a sensor-based architecture that supports the operation of energy consuming technical systems with the aim to achieve energy efficiency in a building and develop an eco-aware behavior to the residents of it.

The whole smart building is controlled by a smart management system which is a connection among the building and the residents of it. The Building Energy Management System, (BEMS), interacts with a wireless sensor and actuator network in order to collect data from the surrounding internal and external environment. Then, it stores the data to the cloud and then use those data for controlling actuators and technical systems.

The BEMS also interacts with the residents of the building in order to be informed about their thermal and lightening feeling. Therefore, the BEMS is user-friendly and aims to monitor and coordinate all technical systems, provide warnings and notifications, apply adjustments and devise strategies with a view to evaluate energy consumption, reduce energy costs and offer indoor convenience to the residents of the smart building.

Firstly, the solution for ensuring energy efficiency in a building focuses on the envelope of a building in order to face insulating problems. Concrete is the major building material used in construction industry. In [27] the authors propose to use in buildings: concrete block walls of 140mm which are plastered expanded, polystyrene of 350 mm for roof insulation, concrete of 200mm for exposed floors and internal floors and for stairs and internal partitions concrete of 100mm, in order to solve insulation problems. In the state of the art, biobased building materials such as hemp concrete is referred. According to [28] hemp is a renewable resource which stores Co2 and therefore contributes in the reduction of gas emissions.

Furthermore, smart materials in [29] are explained to have the ability to respond to the environmental changes that they are exposed to, such as pressure, temperature and wind. Concrete is a low-cost material and easily available, but has the tendency of cracking in difficult environment conditions and consequently reduces the lifetime of the structure. The author describes a new type of smart concrete that contains dormant bacteria which when they come into contact with water, they create limestone, filling up the cracks and thus creating a self-healing repair mechanism. So, the smart concrete increases lifetime of the structure and reduces building cost. Another type of smart material is referred in [29], aerogels which have low thermal conductivity and therefore, they can be used in building construction, indoor air-purification and fire retardation. They also have insulating properties, sound and heat retarding properties.

Lastly in [29] transparent concrete is described. This is concrete that contains fiber optics inside. This material can transmit light and the room will be naturally illuminated and can also use the optical fibers as heat insulators. Both of these characteristics of the transparent concrete intend to ensure energy savings and reduced costs.

Therefore, at this point, we suggest for the eggshell of a smart building, concrete with dormant bacteria for the external of the building. This is because a structure exposed to any environmental conditions should ensure to the residents not only comfort but also life-enhancing infrastructures. Through the self- healing repair mechanism which fills up the cracks with limestone this is achieved. We propose transparent concrete for the inside walls of a building, because it ensures natural illumination inside through fiber optics and also heat insulation. Especially, to build the inside walls of a room as a kitchen, we propose Aerogels that ensure air-purification, fire retardation and have sound retarding properties.

We also propose that the low cost, screen printed, resistivity sensor which is presented in [8] should be implanted in concrete during the construction of the building in order to

TABLE 5. Papers examined about smart solutions for smart buildings.

Technical System	Smart Tech Tools	Smart Solution	Author	Year
AC	Sensors	Control the AC by monitoring air temp and hum	A. M. Ali et al.[22]	2019
DHW	sensors	Hot water is supplied by predicting occupant's behavior, saves heat	T. Sonnekalb et al.[20]	2019
DHW	Sensors and actuators	The unused rooms are not supplied with hot water, saves heat	İ. Ilhan et al.[19]	2019
Eggshell, Heat	Phase Change Material inside walls and sensors	Store heat in PCM panels and achieve heat on request	R. Wegmueller et al. [6]	2018
Eggshell insulation	Thermal images	Detect insulation problems	N. Khan et al. [7]	2019
Eggshell insulation	Resistivity sensors	Monitor concrete's durability	M. Sophocleous et al.[8]	2018
Electric energy	PV generator connected with storage units and heat pumps	Minimizes the use of electrical grid	P. D. Leo et al.[17]	2019
Electric energy	Sensors controllers and Solar Energy	The utility grid over a time-period is zero	K. R. Babu et al. [18]	2017
Electric energy	Wireless sensor network	Notice unnecessary electrical consumption	D. Alulema et al.[21]	2018
Fire prevention	sensors	Monitor fire, set alarms and water sprinklers on	S. Antonov [11]	2019
Fire prevention	sensors	Cloud based platform manages sensors and id fire	G. Cavalera et al. [12]	2019
Heat	IoT platform and sensors	Optimize the temp of the building, reduce costs	A. Zakharov et al.[15]	2019
HVAC, Lightening, Electric Energy	Sensors for: windows-doors, humidity, Co2, indoor-outdoor temp	Monitor occupancy and adjust room's energy mode	N. Haidar et al.[10]	2019
HVAC, Lightening	Infrared sensors, sensors	Optimizes lightening and HVAC control	G. Alsuhli et al.[23]	2019
HVAC	IoT thermostats	Automatically identifies the thermal model to use in each building's thermal zone	X. Zhang et al.[24]	2019
HVAC	Sensors	Use the optimal operation that maximizes energy savings and indoor comfort	J. Aguilar, A. Garcès-Jimènez et al. [25]	2019
HVAC	Model Predictive Controllers	Comfort inside, cost saving, load energy saving	S. Rastegarpour et al.[26]	2018
Lightening	Led and sensors	Power efficiency, control power dynamically by sensing temp and light	P. G. Jeyasheeli et al.[13]	2017
Lightening	Embedded sensors and controllers in luminaries	Optimize lightening operation	A. Pandharipande et al.[14]	2019
RES, Solar energy Photovoltaic	PV system	Store solar power in PV grid for use when electrical grid is off	N. M. Elsayed et al.[16]	2019
Ventilation	Indoor air quality sensor	Monitor indoor air quality	A. Kumar et al.[9]	2017

implement preventative monitoring by collecting real time measurements as for the condition of the concrete and send those information to the cloud for further analysis and draw conclusions throughout building's lifetime.

Furthermore, sensors should be mounted on the external walls of the building in order to sense the outdoor temperature and humidity. This information will be send to the cloud, so as to adjust the building's indoor environment and manage all the technical systems that operate inside the building in order to ensure comfort to the residents.

Last but not least, referring to the eggshell of a building, we propose to apply Renewable Energy Sources (RES)

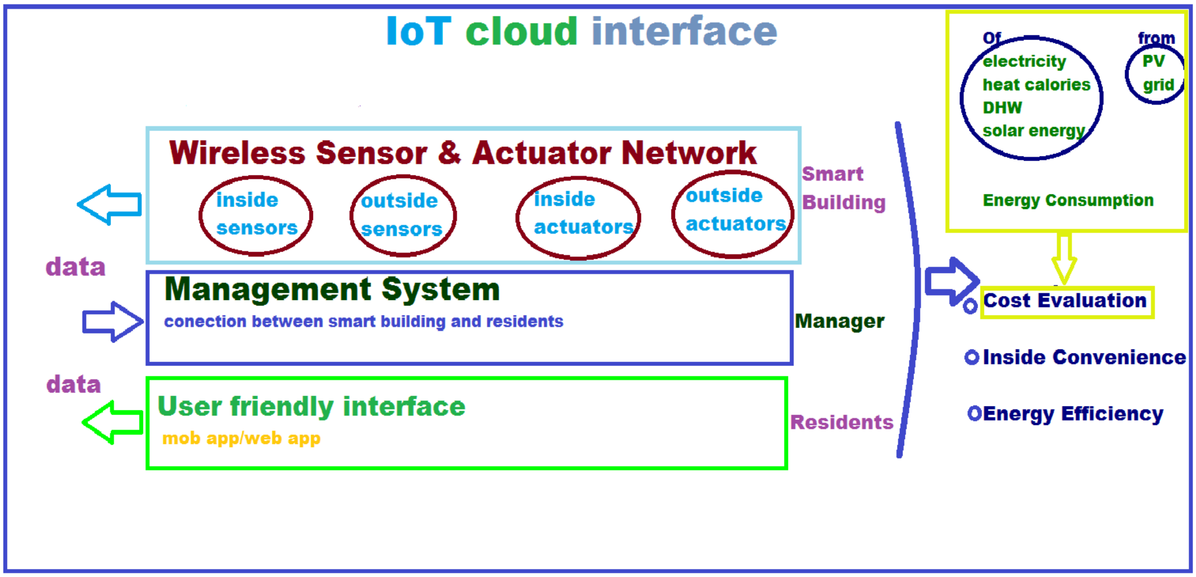

FIGURE 1. The proposed management system for the smart building template.

to optimize a smart building's operation. By installing on a building's roof, Solar Energy Photovoltaic (PV) systems, which allow to store and exploit solar power, gas emissions will reduce and electrical power consumption, too.

To continue with the indoor conditions in a smart building, the most important information to begin with is the occupancy of each room, because a smart building should serve the occupants and adjust its environmental conditions according to their needs. Sensors inside a smart building can be used to collect data during a specific time interval referring to each room's temperature and indoor humidity. Acceleration sensors on windows and doors inform the BEMS about changing doors' and windows' state [23] and infrared sensors [30] check occupancy in a room. Those data will be sent to the cloud and the management system will act and manage all technical systems with accuracy ensuring a friendly and energy efficient environment inside.

The indoor Air Quality sensor that is presented in [9] which is low cost and energy efficient will monitor the indoor air for Co2, Co, O3 levels and send this information to the cloud. Then, the management system will set on or off the ventilation according to the levels of fresh air absence and the weather outside. The management system, see Fig.2, will check the cloud for the information that the sensors in the external walls of the building sent about humidity and temperature outside and also check online weather conditions and if they are favorable, through actuators and servo-motors the windows may open.

The SAFETY Project [12] can be used to predict and face a possibility of fire in the building. The sensors will sense carbon monoxide and smoke presence in order to identify a fire burst. The information will be sent to cloud in order to activate fire alarm, ventilation, actuators for doors, windows and response sprinklers through the management system, see Fig.2.

To continue with the HVAC technical system of the smart building, as mentioned above, we propose the utility of RES in order to reduce energy consumption from the grid and to avoid the use of fossil fuel that provokes gas emissions which contribute to the contamination of the environment.

Photovoltaic thermal panel named PVT are also listed in RES and can be easily mounted on a building's roof. A PVT system [34] uses photovoltaic and solar thermal components to produce both electricity and heat at the same time composing one integrated system which is capable of satisfying the needs of a household to a sufficient extent. Consequently, the thermal energy supplied by a PVT system can be used to cover the heat demand of a building. However, when there is low heat demand like in summer, the heat supply can exceed the demand [34], which means, surplus heat which is the thermal energy that if it is not utilized by any technical system, it will be then released to the environment. This important fact will be used in the following technical systems that are developed below.

To provide heating in a smart building, we propose Thermal Energy Storage and the use of heat pumps, which in a dynamically and economic way allows load shaping and the storing of thermal energy during off peak hours. The management system is following on demand control approach to manage weather conditions and electricity price in order to ensure comfort inside the building and also achieve energy efficiency. The thermal storage tank will firstly store energy from a Photovoltaic (PV) panel and if it is off peak period and the storage tank is not full, then it will store energy from grid. This energy stored in tank is thermal energy and the management system during the peak hours will release it to

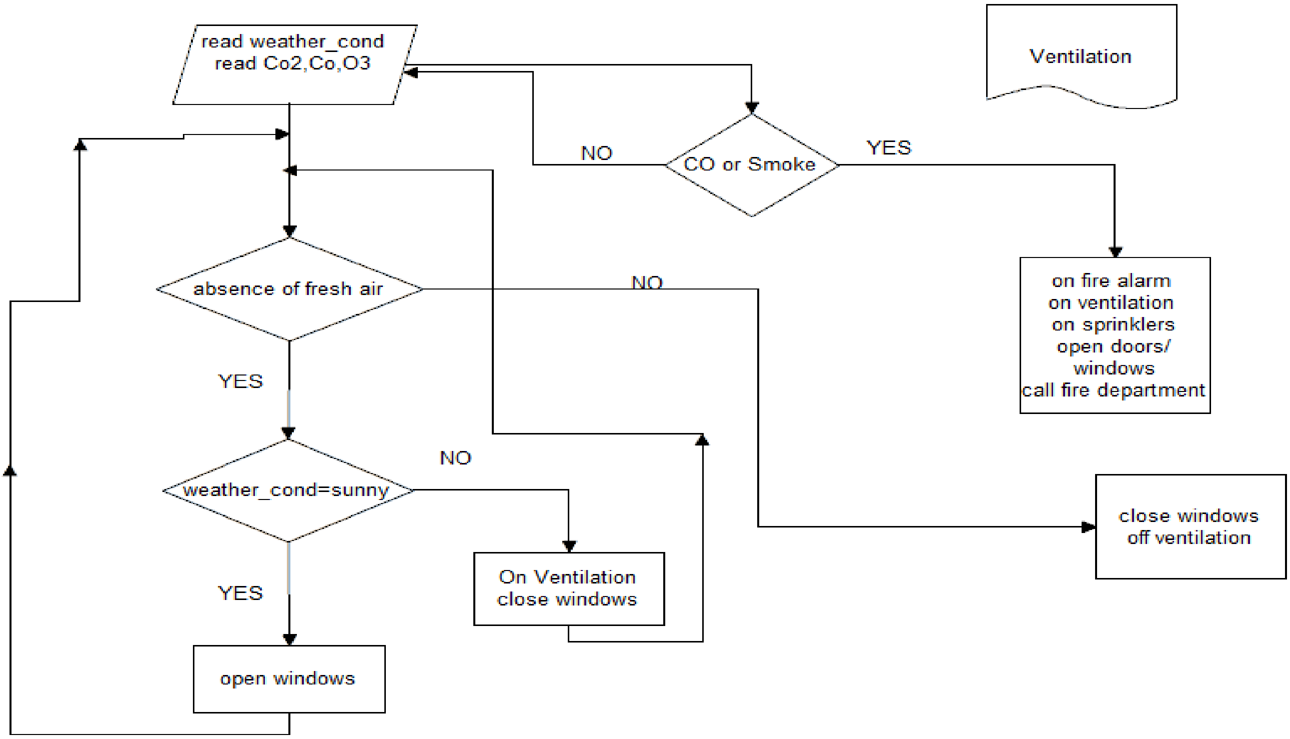

FIGURE 2. The proposed ventilation system.

cover thermal needs [26]. The management system will act as described in Fig. 3.

Firstly, the management system will check occupancy in every room through infrared sensors, in order to cut off the heating in unoccupied rooms and try to maintain the default temperature that was inserted from the user, see step1-Fig.3.

In the meantime, the management system, see step2-Fig.3, will check the weather through sensors: if conditions are favorable will store energy from the PV panel to the tank.

The management system considers also energy supplies in tank (tank_storage), inside temperature, heating set point from the user and period. If inside temperature equals to heating set point and therefore desirable temperature inside is achieved and it is peak period, then the management system will be able to sell energy to the grid, see step3-Fig.3. Otherwise, if it is off peak period and also the tank is not full from energy provided from the PV panel, then energy from the grid is going to be stored in the tank, see step4-Fig.3.

In case the management system is informed by the sensors that the inside temperature is lower than the heating set point that was inserted from the user and in addition, the room is occupied, then, if there is energy supplies in the tank, the supplies will be used to achieve heat comfort inside, see step5-Fig.3. Otherwise, if the supplies of energy in tank are zero, then the management system will use energy from the grid to fulfill the needs of heat and comfort inside for every room of the building, see step6-Fig.3.

In summer, cooling is of great importance for the building's indoor conditions and the occupants' comfort. It is also obvious that the heat supply from the PVT system exceed the heat demand, which is possibly turns to zero. Therefore, a cooling system, that uses Air conditioners driven by an absorption chiller that uses the heat surplus from PVT panels, is proposed for the smart building's air conditioning [34].

The functionality of the proposed system is that the absorption chiller takes the surplus heat of a PVT panel to produce cold water that can be used to satisfy the demand for cooling the building.

Therefore, thermally comfortable indoor environment in a smart building is ensured in an energy efficient way. The management system actions follow in Fig. 4. The management system takes consideration of the infrared sensors to check occupancy in a room, acceleration sensors to check the status of doors and windows and also the sensors that inform for the inside and outside temperature and humidity. Then the decision is taken dynamically and with respect to energy efficiency, whether to switch off or on air conditioning and even close windows and doors. We also propose that the management system should also interact with a user in order to insert his/her thermal feeling [22] for each room and then manage and adjust all technical systems.

As for DHW, the management system should consider occupancy in a room by checking the information given from infrared sensors and cut the supply of hot water in every

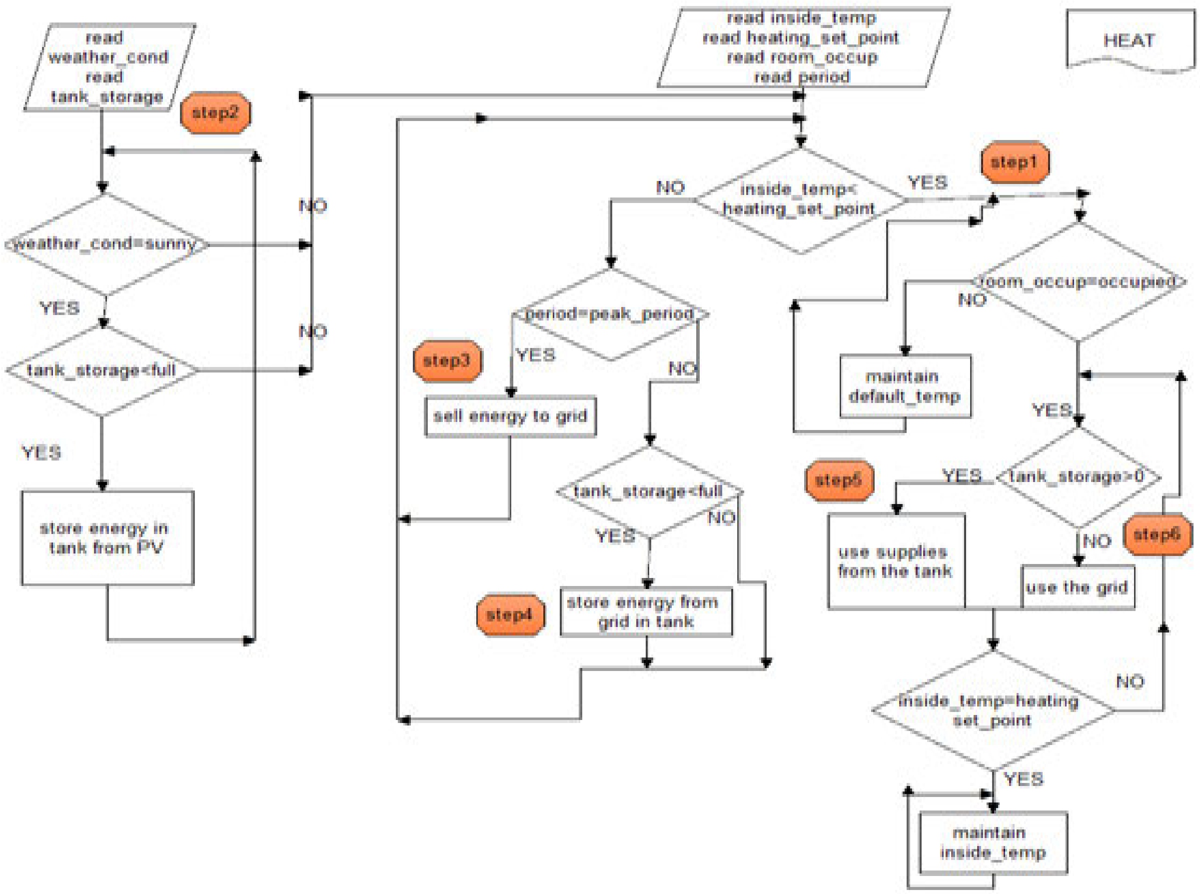

FIGURE 3. The proposed heating system.

unused room, see step2-Fig.5. In this way, heat calories are saved and energy efficiency is achieved. We also propose to use in a smart building a solar water heating system (SWH), which is a structure that transfers solar energy into thermal energy [33]. The system uses a solar flat collector, a storage tank for the hot water and heat pumps.

We suggest that an electric heater that produces heat energy in the absence of solar energy will be useful in order for the thermal system to be reliable. The approach that the system is following is on-demand control approach that aims to maximize the utility of solar energy because this approach uses firstly solar energy to heat up water and stores the surplus solar energy, see step3-Fig.5, into the tank for future usage. Only when solar energy supplies run out, then electric heater is turned on, see step4-Fig.5, by the management system and therefore electricity cost is reduced and energy is saved.

As far as how to achieve savings in electrical energy consumption, we propose the use of smart sockets in a smart building to control autonomously and remotely all electrical devices [31]. We propose that when the infrared sensors inform the management system for an unoccupied room, see step1-Fig.6, then the power should be cut off for all the electrical appliances that are connected to the sockets, even if they are switched off or placed on standby mode.

We also suggest the use of the real-time system [21] which collects data from sensors that sense the current consumed, see step3-Fig.6, by electrical appliances and the supply voltage, in order to monitor the variation of consumption in each room at a specific time interval. Then, the management system will cut unnecessary electrical consumption and relocate the demand of electricity in the building.

These are proposed with a view to achieve electric energy savings during the day to day functionality of the building.

As far as what concerns the electrification of the building, a PVT system will electrify the building and electric energy from the grid will be used only in case the electricity supplies from the PVT system run out, see step2-Fig.6.

We continue with the lights which are of great importance for the convenience of the occupants and should provide optimum operation but also reduce energy consumption. Firstly, we propose the use of LED lights for the whole building area. We suggest sensors to sense lights' intensity inside every room of the building and the management system should also consider the light intensity that the user inserts in the system as ideal. Integrating Light actuators in the lights will turn the

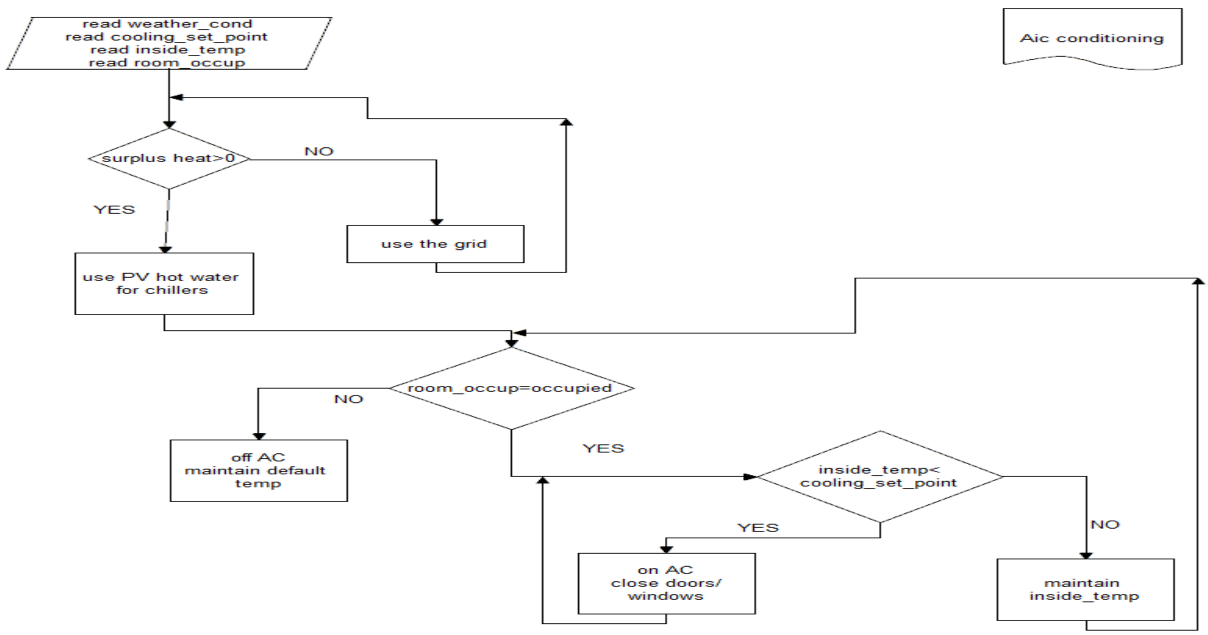

FIGURE 4. The proposed AC system.

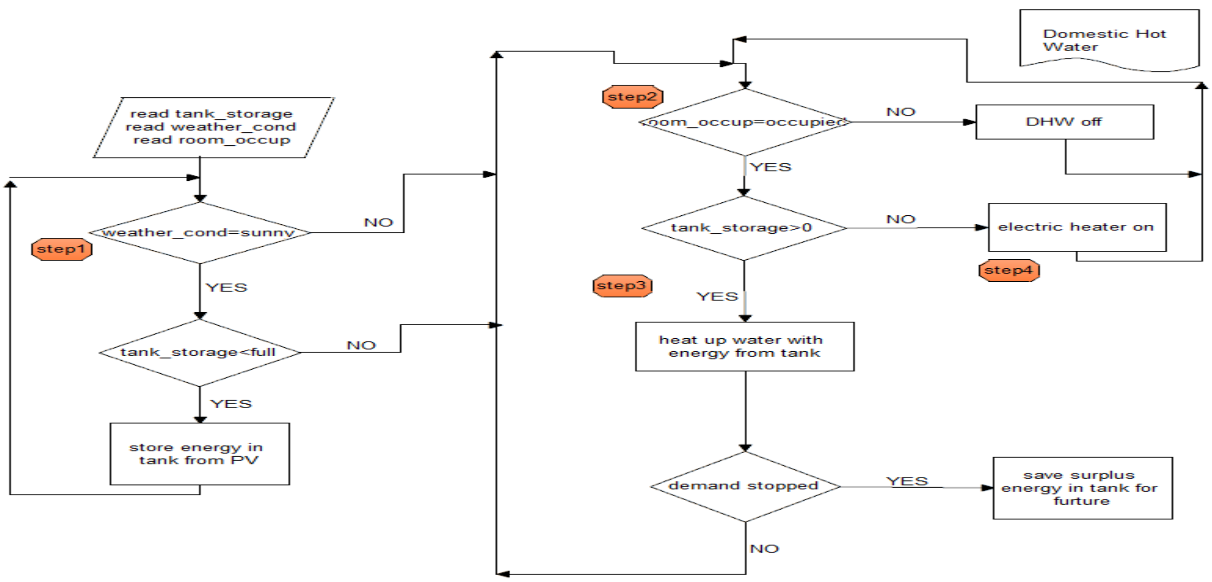

FIGURE 5. The proposed DHW system.

lights off when the management system is informed from the infrared sensors for an unoccupied room, in order to ensure power savings.

Moreover, light sensors should be mounted on the external walls of the building to sense the surrounding light. When the management system is informed for the outside surrounding light, then directions can be given to open curtains through actuators and also awnings [32] so as to let the sunlight in, switch off the LEDs and therefore save energy, see Fig.7

The most important element of this smart building template is the wireless sensor and actuator network, see Fig. 8, which is responsible for informing the BEMS with vital data during a specific time interval, in order to act in an optimized way regarding energy savings.

As described in detail above, this network in Fig.8 consists of inside and outside sensors that sense the surrounding conditions and inside and outside actuators that operate on the BEMS direction. Every sensor has an initial state which changes, after sensing, to a final state. This happens after a specific time interval which is defined from the user of the management system. According to the value of each state, the management system drives all technical systems to adjust.

To summarize, the proposed management system for a smart building intends to offer value to the residents by ensuring their inside convenience and reducing their functionality costs by cutting off power in all technical systems in case of unoccupied rooms. It also achieves energy savings by using RES and replacing the unreliable existing technical systems. Lastly, it reduces gas emissions, which is vital for the environment, regarding a city with energy efficient buildings.

IV. MONITORING ENERGY CONSUMPTION IN EXISTING BUILDINGS

This section discusses an optimally way for monitoring energy consumption in existing buildings. This remote and automated approach can be used for the supervision of a building and can contribute in Building Certification and compliance checking.

At first it is important to refer to European standards, as for energy performance of buildings that are defined and developed from CEN, the European Committee for Standardization. Those standards state the energy requirements of a building and consult the experts in Building Certification and in energy efficient Building construction.

According to [35], a building is separated in zones which are defined in respect of the activities that are carried out on them and the conditions that are required for each of those activities. This standard fully specifies an hourly method modeling for each building zone.

To begin with the system level, regarding the HVAC system of a building, the energy balance for heating and cooling should take into account the following: the energy requirements for the heating and cooling needs of every building zone; the energy provided to the HVAC system from renewable energy systems; the input energy provided after all to the HVAC system; the losses of energy that come from the buildings' eggshell and the operation of the HVAC system (actions like production, storage, distribution, transmission of energy).There are two issues regarding the indoor environment of a building and they are related to the distribution of temperature inside a room and the achievement of converting the inside conditions to the required heating or cooling temperature, taking into account energy consumption.

Temperature variation adjustment is a major issue. Vertical room temperature variation increases the average air temperature and therefore the heat loss in rooms with great height between down floor and up floor. Usually, HVAC systems that can reduce heat loss depending on the height between up and down floor (room height), consume more energy for their operation.

If we suppose that there is a linear temperature change in height with the required comfort temperature tc maintains at 1.5 m above the floor, at this height the air temperature is t1.5.

The average air temperature is

$$t_{av} = t_{1.5} + \text{grad} * (h/(2 - 1.5)) \tag{1}$$

where, h is the room height and grad is the temperature difference between up floor height and down floor height, K/m.

Supposing that surface temperatures in a room remains unaffected, the temperature during operation of the HVAC system is: $(t_r + t_{1.5})/2$, so the rated heat loss is:

$$U * ((t_r + t_{1.5})/2 - to) \tag{2}$$

Ignoring how the losses vary between floors, walls and ceilings, the real heat loss is: $U * ((t_r + t_{av})/2 - to$

The heating requirement for a room [36] is:

$$Qt = (ti - to) * \left(U' + V\right) - dt * V \tag{3}$$

where:

ti is the room temperature

to is the outside air temperature

U′ is the total conductivity associated with the building material (U′ = U * A), A is the floor area.

V is the ventilation conductivity.

$dt = k * Qt$

Replacing and rearranging, we have:

$$Qt = (ti - to) * (U + V)/(1 + k) \tag{4}$$

The usual heat requirement is multiplied by a factor of 1/(1 + k). Given k, V ventilation conductivity is 0.33N * room_ volume, where N is the ventilation rate in ac/h, (air changes per hour).

Thus,

$$k = 2 * a * r * d * 0.33 * N * room\_volume * \frac{\eta r}{\eta t * A} \tag{5}$$

room_volume/A is equal to room height, h. The standard value of α is 0.9, of r is 0.123, of ηr/ηt is 0.5 and represents the proportion of energy produced due to transmission.

The energy requirements of the building for heating [35] each zone of the building, for a period of time (usually per month) is calculated as follows:

$$Q_{NH} = Q_{L,H} - \eta_{G,H} * Q_{G,H} \tag{6}$$

Provided that $Q_{NH} \geq 0$

Where, (for every building zone and for every month):

Q_{NH} is the building energy requirement for heating, in MJ

$Q_{L,H}$ is the total heat transfer for the heating period, in MJ

$Q_{G,H}$ are the total heat sources for the heating period, in MJ

$\eta_{G,H}$ is the two-dimensional profit-making factor. It is a function mainly of the gain-loss ratio and the thermal inertia of the building.

The energy requirement of the building for cooling [35] each zone of the building, for a period of time (usually per month) is calculated as follows:

$$Q_{NC} = Q_{G,C} - \eta_{L,C} * Q_{L,C} \tag{7}$$

Provided that, $Q_{NC} \geq 0$

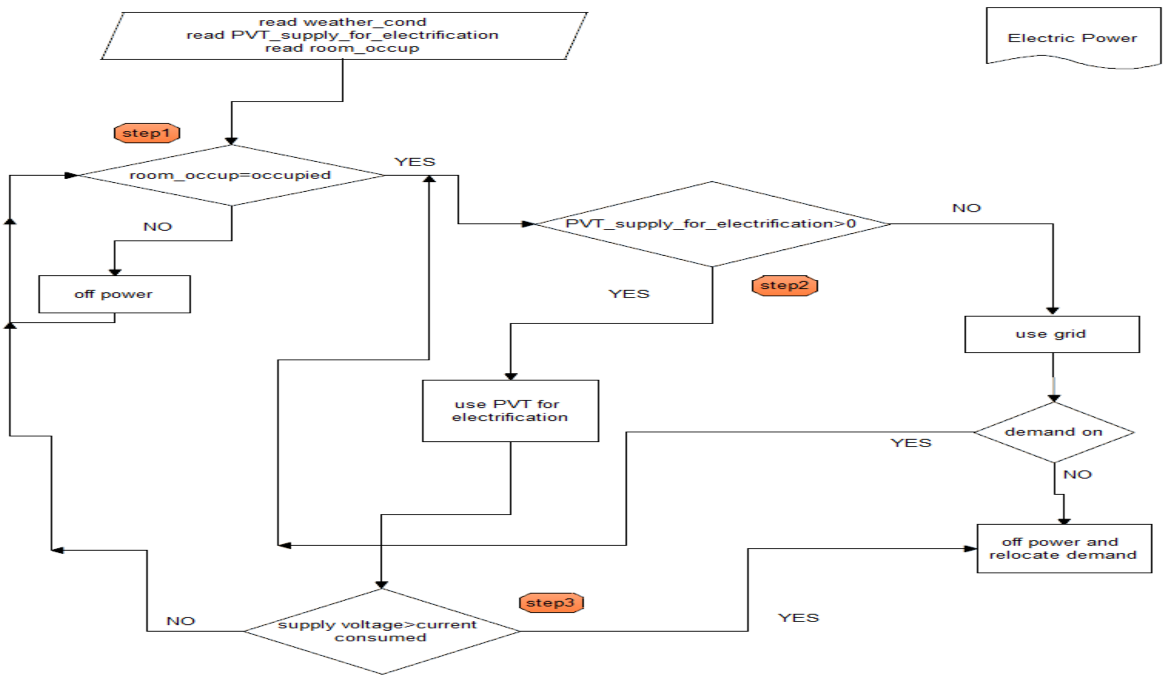

FIGURE 6. The proposed system for electrification.

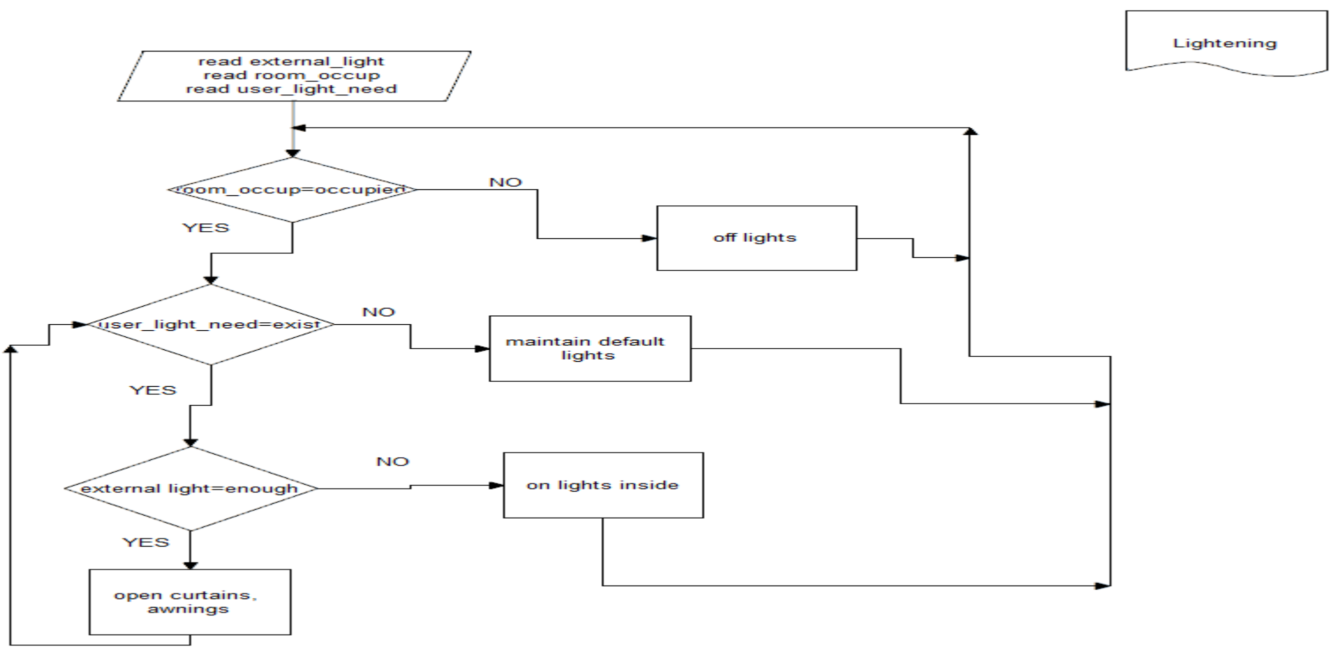

FIGURE 7. The proposed lightening system.

Where, (for every building zone and for every month):

Q_{NC} is the building's energy requirement for cooling, in MJ

$Q_{L,C}$ is the total heat transfer for the cooling period, in MJ

$Q_{G,C}$ are the total heat sources for the cooling period, in MJ

$\eta_{L,C}$ is the dimensional factor of using heat loss. It is a function mainly of the loss-to-profit ratio and the inactivity of the building.

The total heat transfer in a building Q_L, is calculated as follows:

$$Q_L = Q_T + Q_V \tag{8}$$

where, (for each building zone, and for each month):

Q_L is the total heat transfer, in MJ

Q_T is the total heat transfer from transmission to MJ

Q_V is the total heat transfer from ventilation to MJ

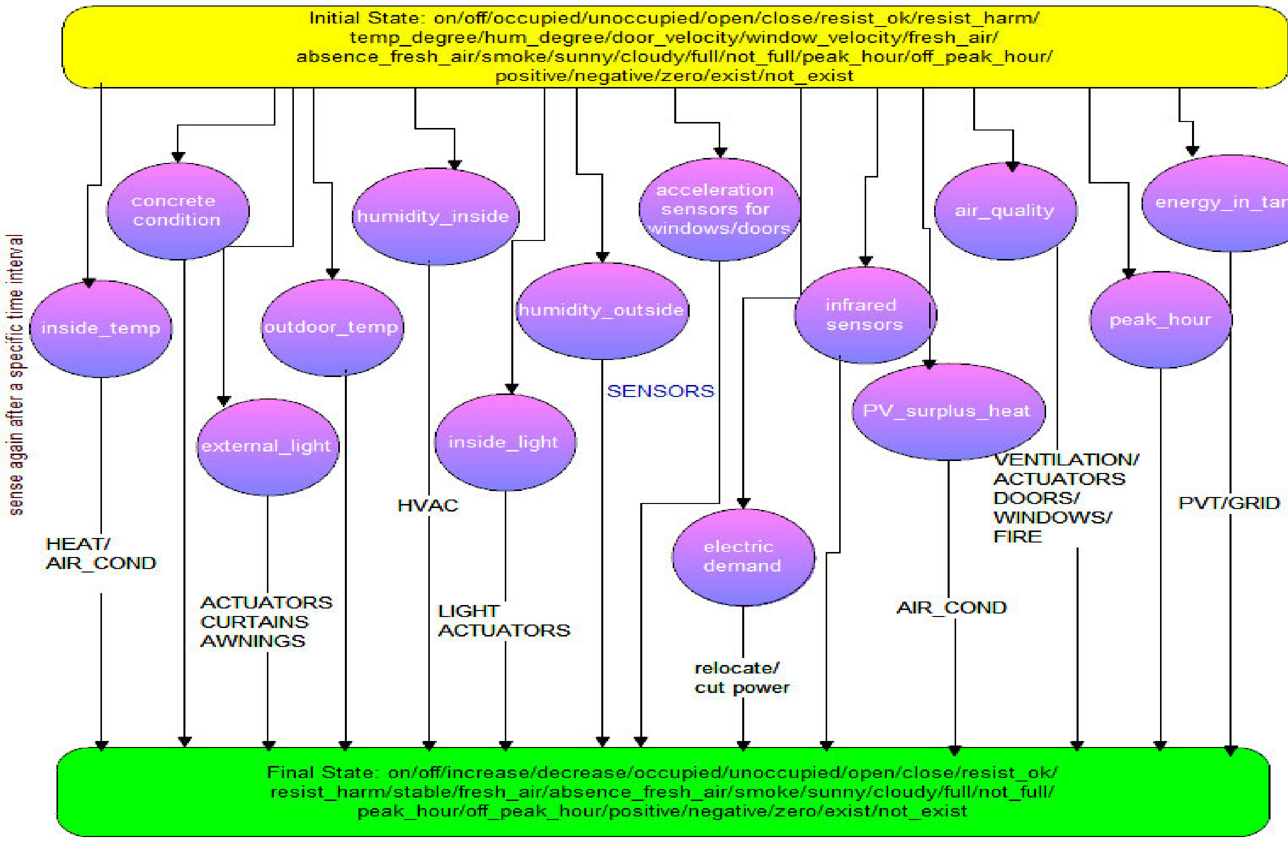

FIGURE 8. The proposed wireless sensor and actuator network.

The total heat sources, Q_G, of the building zone for a given calculation period, are:

$$Q_G = Q_i + Q_s \tag{9}$$

where, (for each building zone, and for each month of calculation period):

Q_G are the total heat sources, in MJ.

Q_i is the amount of internal heat sources during a given period in MJ.

Q_S is the amount of solar heat source during a given period, in MJ.

The total heat transfer from transmission is calculated for each building zone z and for each month, as follows:

$$Q_T = \sum_k \{H_{T,k}(\theta_i - \theta_{\varepsilon,k})\}tf \tag{10}$$

where, (for each building z zone, and for each month):

Q_T is the total heat transfer from the transmission, in MJ

$H_{T,k}$ is the heat transfer coefficient from the transmittance of element K to a room, the external environment or zone with the temperature $\theta_{e,k}$, in W/K. The values for the $H_{T,k}$, of element K shall be calculated [37], taking into account the standards for the specific elements such as windows [38], masonry and ceilings [39], and floor in contact with the ground [40].

θ_i is the internal temperature of the building zone, in degrees Celsius obtained from the activity database (designated heating point)

$\theta_{e,k}$ is the outside (atmospheric) temperature (the monthly average temperature obtained from hourly climate data of the position)of element K, in degrees Celsius, as obtained from the climate database t is the length of the calculation period, i.e., the number of days per month, f is a factor for the conversion from Watt hours to MJ.

The total heat transfer is done by summing all the building elements that are part of the building and separating the interior from the outdoor conditions. We should note that heat transfer or part of the heat transfer may have a negative sign during a certain period of time.

The Domestic Hot Water requirements for each zone [41], is calculated as follows;

$$\text{DHW Requirement (MJ/month)} = \text{Database Requirement} * 4.18/1000 * ZoneSize * \Delta T \tag{11}$$

where;

Database requirement = l/m^2 (per month) from activity database.

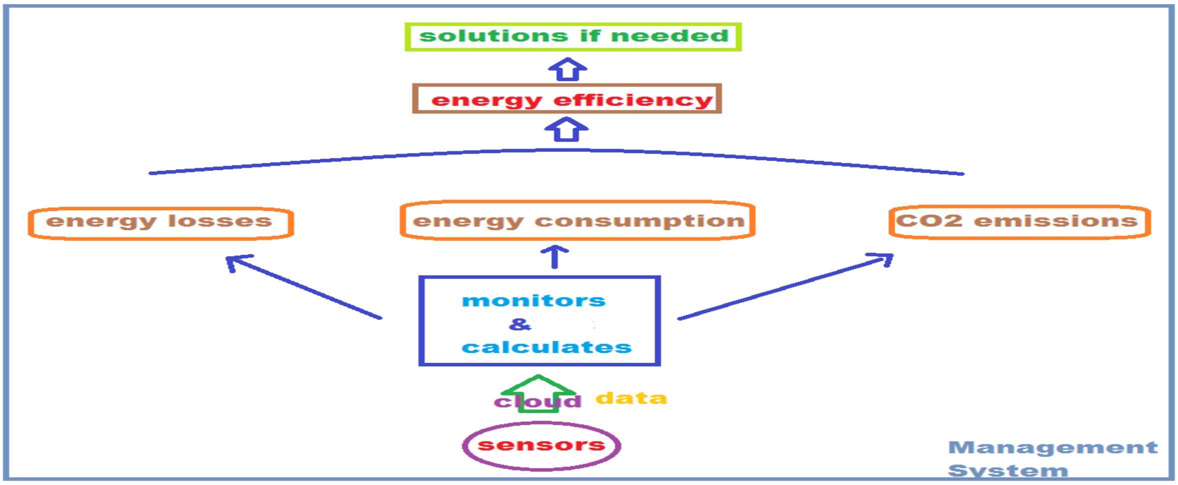

FIGURE 9. The proposed management system for existing buildings.

ΔT = temperature difference (degree K when the water is heated) is considered as 50K.

4.18/1000 = specific heat of water in MJ/kgK

The Lighting energy requirement is calculated below [42]. The input data in this calculation include the lighting power, the duration of their operation, lighting equipment including the effects of building users, and conditions that consider the contribution of daylight under different control conditions.

Lighting Equation:

$$W_{light} = \frac{\sum_{j=1}^{12} [N_j * (\sum_{i=1}^{24} [P_j(F_{Dji} * F_{Oji})]) + 24 * (P_p + P_{dj} * F_{Od})]}{1000} \quad (12)$$

where:

N_j = [31, 28, 31, 30, 31, 30, 31, 31, 30, 31, 30, 31]. Number of days randomly chosen, in each month

P_j = Light Power in W/m2 for each hour of the month j

P_p = Parasitic power in W/m2/hour

P_{dj} = Power of projection lighting in W/m2 for each hour of the month j

F_{Dji} = Daylight Correction Factor for Time i of Month j

F_{Oji} = Building Correction Factor for i hour of the month j

F_{Od} = Usage correction factor for projection lighting throughout the year.

Considering the European standards, the management system that we propose for existing buildings is an IoT sensor oriented system. This system is going to use information provided through sensors connected to cloud for a specific period of time, in order to conclude the energy losses of a building, the energy consumption of all technical systems that operate in this building and the Co2 emissions that derived from them. Then this information will be used to calculate whether the building is energy efficient. At this point the management system regarding which technical system is energy inefficient will suggest solutions to minimize the ineffective energy performance of the building. The proposed management system for existing buildings that manages energy performance is shown in Fig.9.

The minimum required sensors that we suggest in order to extract the required information are visualized in Fig.10. The sensors sense the temperature, the light and the air quality inside a room. Sensors also sense the temperature and the humidity outside and then they inform the management system of the current conditions so as to drive all the technical systems; Heat, Ventilation, Air Condition, Lights and Domestic Hot Water, through actuators. During the technical systems' operation the management system also calculates energy losses, the consumption of electric energy and the total amount of Co2 emissions.

At this point we have to apply an efficient design for interactions between sensors and cloud.

In [43], an efficient interactive model is developed "for the sensor-cloud integration to enable the sensor-cloud to simultaneously provide sensing services on-demand to applications with various latency requirements". In this method, complicated operations are loaded to the cloud, and only the light-weight processes are served by sensor nodes.

For the development of this sensor-cloud method the authors define the following:

i. Physical sensor nodes which collect data from the real environment and send them to sensor-cloud.
ii. Sensor-cloud which illustrates the physical nodes into the virtual sensors.
iii. Applications or users that request the sensor-cloud for sensing services on demand periodically, with different latency requirements.
iv. A QoS controller implemented on the sensor-cloud to control the latency of sensing flows, gather feedback

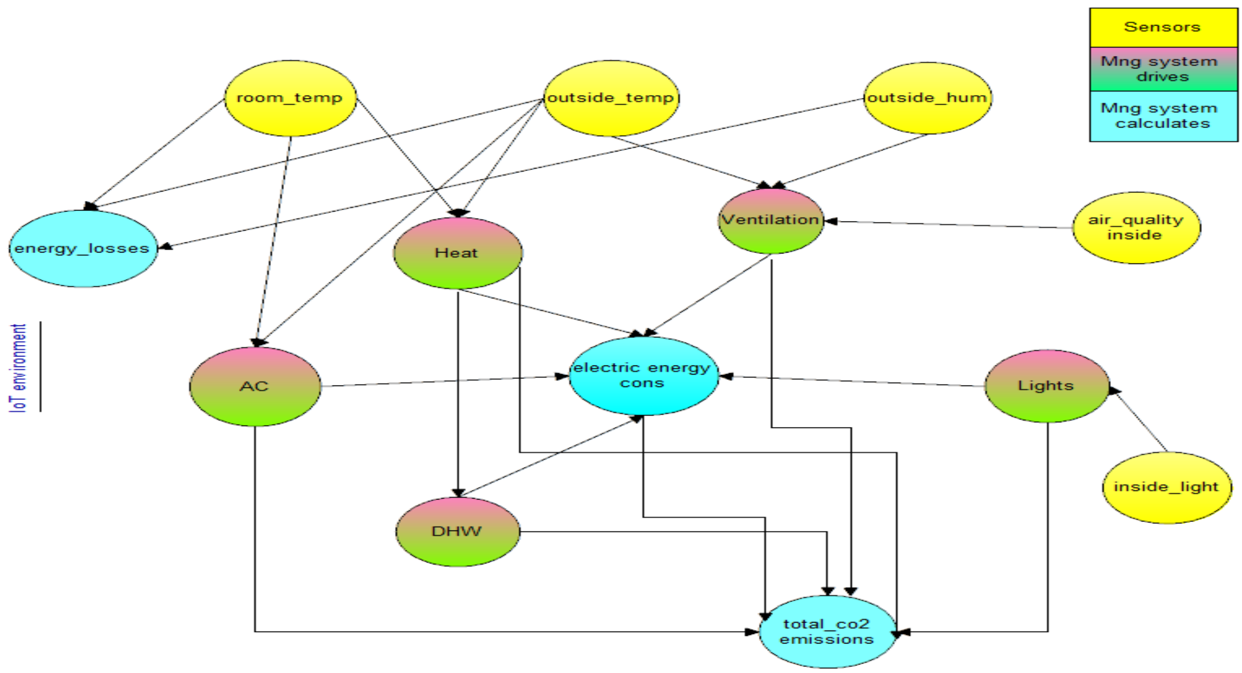

FIGURE 10. Connected Sensors inform the management system to drive technical systems and calculate.

information from sensing flows, compute control parameters, and guide sensor nodes through scheduling controller.

v. The scheduling controller implemented at physical sensors is used to schedule sensor nodes according to QoS controller and in this way latency requirements of the applications are satisfied while energy consumption of sensors is optimized.

vi. A mechanism for interactions between the QoS controller on the sensor-cloud and the scheduling controller at the sensor nodes, in order to automatically adjusts the wakeup schedule of sensors to satisfy applications' latency requirements.

The authors' model is developed based on a down-stream from cloud-to-sensors for serving application requests and an up-stream from sensors-to-cloud that serves sensing traffic.

To begin with physical sensors modeling, each sensor has an ID which is a unique integer, type i_τ with

$$i_\tau \in \tau = \{\tau 1, \tau 2, \ldots, \tau_N\} \tag{13}$$

a set of sensor types (such as temperature, humidity,..) registered with the sensor-cloud: S, which represents scheduling parameters (such as wakeup and sleep interval). For a sensor node i:

$$i = (i_{ID}, i_\tau, i_S), \quad i_\tau \in \tau \tag{14}$$

To continue with a sensor- cloud c, it is described also with ID, a set of τ sensor types, and price options P (such as price P1) for sensing services with the QoS, Q_1 (such as packet latency) provided by a sensor. The price which sensing service consumers are charged depends on the QoS packet latency that they request (such as, $P_1 > P_2$ with $Q_1 < Q_2$). For the sensor-cloud c model:

$$c = (c_{ID}, c_\tau, c_p) \tag{15}$$

The authors in order to characterize an application α use: ID, a set of sensing data types of interest α_{SI} (such as temperature, humidity,..), a region of interest α_{RI} (such as sensors in the region R_{E1}) and quality of service requirements (such as packet latency L_r^α requirement, sensing interval, or data accuracy).

The authors describe that every new application, α, requests a sensing service from the sensor-cloud system, giving region of interest and packet latency requirement. An application α is modeled as:

$$\alpha = (\alpha_{ID}, \alpha_{SI}, \alpha_{RI}, L^a{}_r) \tag{16}$$

The application requests are then forwarded to the Request Aggregator for processing. The aggregator is looking for a new latency requirement for the physical sensors. If the aggregator does not find any change in latency requirement then the application request is hidden from sensor nodes.

The authors explain that if a new requirement for latency is found, the aggregator pushes it to the QoS controller for latency requirement update. The QoS controller processes the new request first by checking, if current situation satisfies the new request or not. If current situation satisfies the new request, the request is then hidden from physical sensor nodes. If not, the QoS controller calculates a new queue threshold for physical sensors. Then the sensor management system sends the queue update to physical sensors. The physical nodes update their queue threshold as well and adjust their schedule for execution.

The sensor management system, according to [43], uses a mapping function to map a set of physical sensor nodes ζ

$$\zeta = \{p_1, p_2, p_3, \ldots\} \tag{17}$$

With p_i is the i^{th} physical sensor, to a set of virtual sensors γ

$$\gamma = \{v_1, v_2, v_3, \ldots\} \tag{18}$$

with v_i is the i^{th} virtual sensor

$$f_{phy\rightarrow vir(\zeta)} = \gamma \tag{19}$$

and vice versa

$$f_{vir\rightarrow phy}(\gamma) = \zeta = {f_{phy\rightarrow vir}}^{-1}(\zeta) \tag{20}$$

This implementation of the sensor- cloud system is going to be executed by the Management System that is illustrated in Fig.9.

To continue with the functionality of the proposed management system that is going to be described below, we use a flow chart to illustrate it in Fig.11.

Supposing we have an occupied building to check, the management system should monitor all its technical systems for 24 hours for a specified period of days. The management system will use data from the sensors to conclude energy efficiency of the HVAC system, the Lightening system, the building's eggshell, the use of DHW and the electric power consumption. In case energy consumption is over or equal to the allowed limit value or Co2 emissions is over or equal to the allowed limit value, then the building is not characterized as energy efficient and the management system should suggest actions for the specific technical system that operates in an energy inefficient manner.

To clarify it further, in case the management system concludes that the heating system operates in an inefficient energy manner, it will propose measures to reduce inefficiency. For instance, the placing of sensors in every room will be helpful in order to check and control the temperature accordingly with the residents' feeling of comfort. That means that the residents could use also IoT-based smart thermostats [24] so as to prevent heating system from uncontrolled operation which also results in pollutant emissions and costing in fuel. Choosing smart thermostats over a temperature sensor network is costless and smart thermostats can control the HVAC of a building and monitor indoor temperature because they can reflect the thermal condition of every room. Therefore we are able to develop thermal models according to energy efficiency and the residents' indoor convenience.

Another solution could be the utility of sensors for occupation in every room, in order to cut heat in unoccupied rooms but predict to preserve a default temperature to avoid over-operation for re-heating. If the heating system is centralized then an individual heating system is proposed. If oil boiler is used then, if possible, natural gas is proposed in order to reduce polluted emissions. Solar PV panels could also facilitate the heating system by exploiting energy from the sun for the heating operation and reduce both the consumption of oil and electric power and also the polluted emissions. In case doors' and windows' frame are not appropriate for thermal insulation, due to them we may face energy losses. In this case the heating system should again over-try to heat every room and as a result we have increased heating calories and polluted emissions. Then waterproofing frames and with low heat permeability are proposed. In the same way, concrete supplement should be mounted in every internal or external wall that has a concrete rift, in order to face heat losses.

In case the management system concludes that the AC system operates in an inefficient energy manner, the placing of temperature sensors in every room will be in this case helpful, too. The residents could also use IoT-based smart thermostats, so as to prevent AC system from uncontrolled operation which results in polluted emissions and costing in electric bill.

Sensors for occupation in every room could be used in order to cut AC operation in unoccupied rooms but predict to preserve a default temperature so as to avoid over-operation for cooling. Solar PV panels could also facilitate the AC system by exploiting energy from the sun, in summer especially when solar energy is in surplus and the heating system does not consume it. This way the consumption of electric power and the polluted emissions are both reduced. In case of energy losses which means that the AC system will over-try to cool every room, we propose waterproofing frames and with low heat permeability. In the same way, concrete supplement should be mounted in every internal or external wall. Green roofs will be also useful for a building to keep a cool temperature in a natural way.

In case of an inefficient Ventilation system, motor for windows would be a good solution, provided that the weather and the external temperature allow the opening of windows in order to ventilate every room. Sensors for occupation should also be applied in order to cut electric power for ventilation, save energy and avoid pollutant emissions.

As for an inefficient system that provides the building with DHW, PV solar panels would also be useful in order to reduce Co2 emissions. The utility of solar energy will also decrease both consumption of oil for heating water and electric power.

In case of an inefficient lightening system a good proposal is to replace bulbs in lightening system with Led lights. Furthermore, occupation sensors would contribute in this direction, since electric power would be cut off and all lights would be turned off, in case of an unoccupied room. Finally, motors for curtains should be applied in order to benefit from natural light and save electric energy.

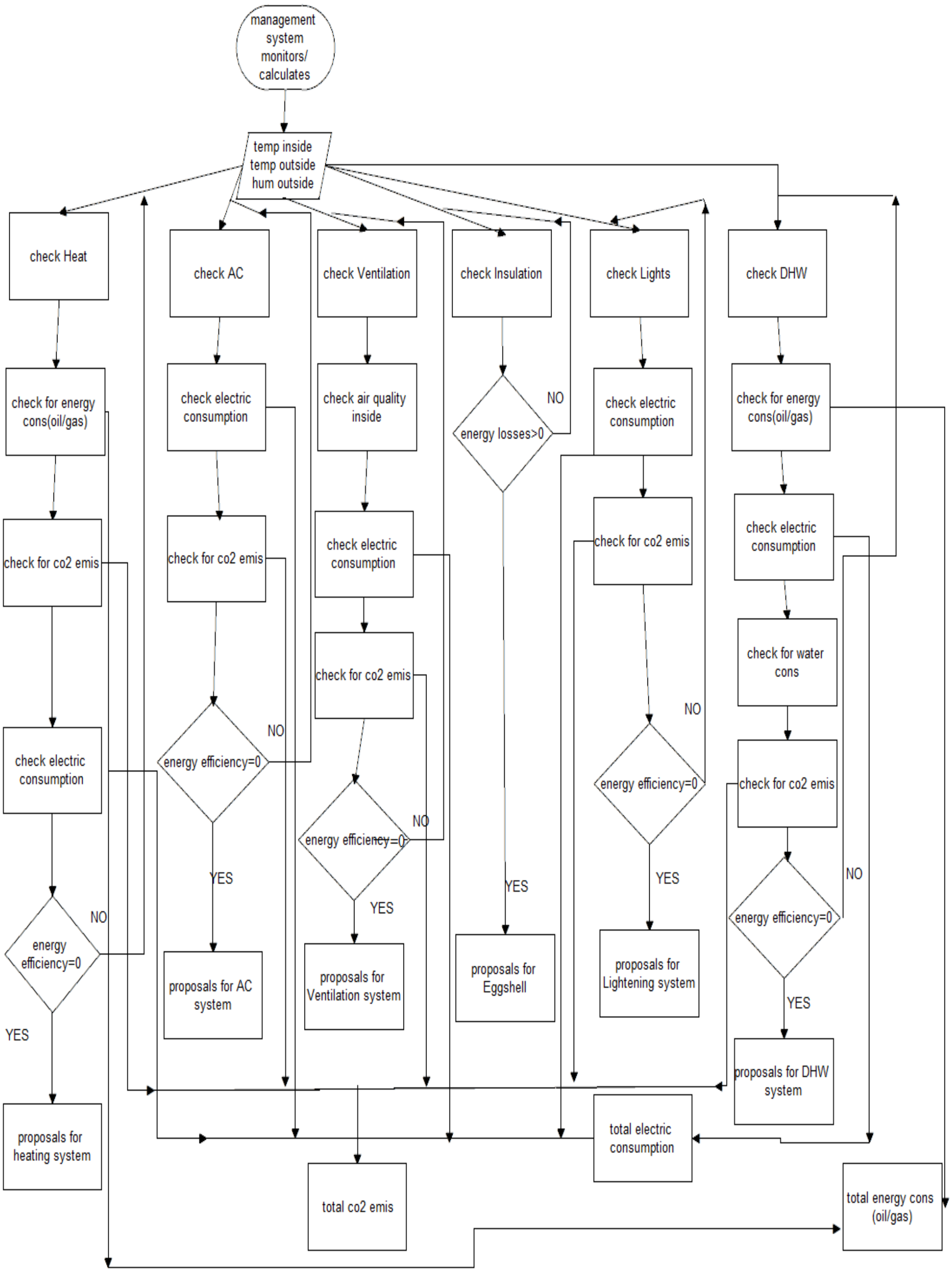

FIGURE 11. Functionality of the management system.

Apart from all the proposals which were mentioned before that aim to reduce electric energy consumption, we could also point out the following solution:

A smart socket system [44] could be used to reduce the consumption of electric energy, achieve energy efficiency and reduce pollutant emissions. This system includes parameter setting and status monitoring.

The resident may enter parameters of each powered device and select different power device priorities. Bluetooth and other wireless communication are used to receive and send data from the building and control electric appliances. The smart socket is responsible for collecting the power consumption data of all electrical devices and for controlling their power-consumption.

TABLE 6. Proposals to achieve energy efficiency.

Increase Energy Efficiency/Decrease	Co2	Heat	Ventilation	AC	Lights	DHW	Electric Energy	Improve Insulation
Green roofs	X			X			X	
Concrete supplement	X	X		X			X	X
Doors/windows frames	X	X		X			X	X
PV solar panels	X	X		X		X	X	
Occupation sensors	X	X	X	X	X	X	X	
LED lights	X				X		X	
Motor for curtains					X		X	
Motor for awnings					X		X	
Motor for windows	X		X				X	
Natural gas	X							
Individual heating system	X	X					X	
Smart thermostats	X	X					X	
Smart sockets	X						X	

Table 6 includes the solutions that the management system would propose both in case of an energy inefficient system and in order to reduce Co2 emissions.

V. CONCLUSION

IoE and IoT can serve the planning of transforming the cities of the European Union into smart and sustainable cities.

These actions not only would be beneficial for the citizens, but for the environment, too.

In this paper we first of all quote the European legislation regarding smart cities in order to show the importance of presenting technology proposals that are legally compatible and applicable to the institution of a smart city. Moreover, we perform an extended literature review in order to collect all representative technology methods that can be applied, with respect to European legislation as for energy efficiency, to smart buildings. We then present a smart template for the stable short-term and long-term construction of energy efficient buildings by using IoT technology. In addition, we are willing to underline our further contribution to the gradually transformation of existing buildings into Nearly Zero energy buildings in European Union, by proposing a management system and solutions for facing and controlling energy inefficiency in existing buildings. The proposed management system may also contribute to the Building Certification and compliance checking of buildings by providing remote and continuous measurements of all building's technical systems.

VI. FUTURE WORK

It is obvious that technological tools and equipment as well as financial support are vital in order to simulate both the smart technology building template and the management system that monitors energy consumption in existing buildings.

These facts were a limitation in our research. Therefore a desirable and reasonable future goal of this research is both the implementation and testing of the management system that monitors and controls the smart building template and the implementation and testing of the management system that concludes the energy efficiency of an existing building and proposes solutions to transform the building, according to the current legislation, into environmentally friendly.

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