OPOTIMIZATION OF ENERGY CONSUMPTION USING MODERN SMART MAKING TECHNIQUES TOWARDS GOALS OF SUSTAINABLE DEVELOPMENT

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ABSTRACT:
Goal of this study is to offer guidelines in order to optimize consumption of energy in buildings using modern smart-making techniques toward achievement of sustainable development goals. Considering high rates of energy consumption and increase in consumption of fossil fuels, the most important approach in designing buildings is to lower energy consumption. According to statistics, 40 to 50 percent of energy in the country is consumed in building sector and causes environmental pollution and destruction. Modern construction technologies which are being widely used in industrial countries are a step toward reducing energy waste. Smart building is among modern construction technologies in architecture that controls energy consumption and largely contributes to optimizing energy consumption and its waste and as well as saving time and expenses of maintaining building apart from comfort and safety that provides within building. Such systems are in full interaction with the environment and reduce damage to the environment. Therefore, in this study, scientific guidelines using energy management techniques in terms of benefits arising from smart buildings and making buildings smart is investigated. Results of this study suggest the possibility of using modern technologies and smart equipment within buildings to optimize energy consumption in residential buildings as a model for architectural plans in order to lower energy consumption toward economic development and interaction with the environment. Using Modern Smart Making Techniques Toward Goals of Sustainable Development

KEYWORDS:
Intelligent Systems, Optimization Of Energy Consumption, Sustainable Development

INTRODUCTION

Today, energy and optimizing its usage within buildings is among important issues in designing buildings. Preserving non-renewable energies and reserving them for future generation is among the approaches toward optimizing energy consumption. Energy optimization is one of the main and effective means of achieving sustainable development. By energy optimization we mean, choosing correct models well as formation and usage of suitable methods and policies as to production and consumption of energy which along with encompassing continuous economic growth, reduces destruction of energy resources and lowers adverse effects arising from incorrect usage of energy on the environment and society.

Reducing dependence on imported energies, lowering costs of producing and consuming energy, reducing environmental destruction and preserving it for future generation as well as preserving energy for future generation are among benefits of energy optimization. Energy consumption in Iran is three times the average consumption of energy in the world and buildings account for about 40 percent of it. This rate suggests the necessity of considering this issue. To this end, related organizations have made a lot of attempts. Ministry of Housing and Urban Development and Construction Engineering Organization have taken steps toward observing part 19 of national building regulations. Considering high rates of energy consumption in Iran and based on the fact that rate of energy consumption in Iran is about three times the average rate in the world, necessity of paying attention to this issue is of special importance. Using modern construction technologies such as making buildings smart is a way of reducing energy consumption. These techniques are common in industrial countries. Such systems are in full contact with the environment and result in energy consumption. To this end, smart building, modern construction technologies, smart systems, smart management system of buildings and controllable equipment within residential buildings are introduced.

Smart building and its implications

In the 80s the word "smart" was utilized for the first time in the United States of America for buildings. Concept of smart building based on development of information technology has been the focus of attention in some scientific resources. Considering studies performed, more than 30 definitions regarding smart buildings have been offered and some of them put emphasis on technology aspects. For example, smart building has been defined as a building with fully-automatic control system. Smart building institute in Washington defines smart building as an integrated set of different systems as to effective management of resources, increasing technical capabilities, saving investment costs, saving operational expenses and flexibility, while some other professionals define it as a building which meets needs of users (residents or visitors). In another definition, smart building is a dynamic architecture which using suitable interactions among four main elements including place (building and facilities), process (automation, control and system), individual (services and users), and management (maintenance and performance) brings about appropriate productivity [1].

Smart building is a building which all of its internal components interact with the environment through integrated system and formation of a consistent logic. In this definition, being smart means that system chooses to make appropriate decisions based on states formed and defined logics. In other words, smart building cannot show creativity against different factors and will behave based on rational inductions [2].

Smart buildings are those buildings in which, information technology and communication systems are merged and result in formation of an integrated system with more comfort, more safety, better economic justification and lower costs. Institute of Smart Buildings defines smart buildings as follows:

"Creating a suitable environment with economic justification using building structure, services, management and their interrelationships".

In general, smart building refers to a building with a strong communication structure; a building which through adaptation to the circumstances can constantly react to changes in the state of the environment. Such factors lead to enhancement of safety and comfort of residents and therefore, residents can use available resources in a better and more effective manner, in the United States of America, smart buildings are defined in this way [3].

Today's intelligent buildings are actually electronically enhanced buildings, the forerunners of a new architecture. They herald an impending paradigm shift in the world of architectural design [4].

Intelligent architecture

Intelligent architecture refers to built forms whose integrated systems are capable of anticipating and responding to phenomena, whether internal or external, that affect the performance of the building and its occupants.

An intelligent architecture relates to three distinct areas of concern [4].

- intelligent design
- the appropriate use of intelligent technology
- the intelligent use and maintenance of buildings

Smart architecture is dynamic. That is, main performance parameters change themselves with regard to the requirement, demand and changing conditions. Just like a living organism, a smart architecture can learn and use its experiences in new circumstances. This way, dynamism and self-organization of the system is guaranteed. Main characteristics of such architecture are as follows: dynamism, activity, flexibility and compatibility with the environment, reactivity and accountability [5].

Intelligent building management system

In today's world, in most countries, smart management of building has a broad range of usages. The most important usage of this management in construction industry is as follows:

In this category, capability of integrated management of building is considered. Therefore, it can be generalized in issues concerning saving energy consumption as well as consumption of all required energies in housing, including thermal energy and electricity.

- Possibility of controlling lighting systems and light in building is among other capabilities of such system.
- Setting emergency state and control of crisis time (e.g. at the time of fire) are other usage of it. Controlling closed circuit televisions in building and controlling entry and exit doors are among capabilities of this system.

Smart management of building is equal to optimized usage of technology and using information technology and computer in order to lower expenses of building industry and saving through consumption management. Integrated system of construction management is a system of smart management and control of building. In better words, such system is a set of direct digital controllers interconnected as a network. Such set of controllers receive information collected concerning such variables as temperature, pressure, wetness, voltage, ampere or performance of equipment like pump, fan, boiler and chiller by sensors and switches and after analysis, send commands to operators and motors such as electricity valves, damper motors, contactors and etc. Performance of management system of buildings is essential for implications of smart buildings. Goal of that control is to monitor and optimize building services (that is, lighting

system, thermal system, safety and alarm systems, controlling access to audio-visual systems and entertainment systems, air conditioning, air filtering and controlling and even controlling time and presence of people and reporting them) [3].

Goals of implementing building smart management

Smart management of building is equal to optimized usage of technology and using information technology and computer in order to lower expenses of building industry and saving through consumption management. Operational goals of smart management of building are as follows:

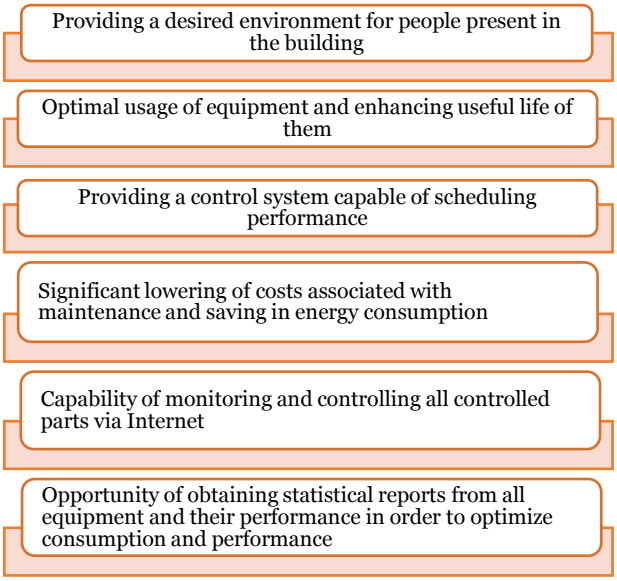

Figure 1: Goals of Implementing Building Smart Management [6].

Tasks of smart management system of buildings

In smart management system using the latest technology it is tried to provide conditions ideal to residents and at the same time, energy consumption is optimized within building. Main objective of such system is to optimally use existing facilities and energy which as a result leads to comfort of residents. Initial investment made for execution of building management system is recovered through saving energy consumption. Such system controls different parts of building and provides suitable environmental conditions. Among capabilities of smart management system of building are smart controls of temperature, safety of building, smart management of firefighting and.... Controlling access to mart management system using related software within building and even outside the building (via internet) is possible. Smart management system enjoys high flexibility which is easily adaptable to different requirements.

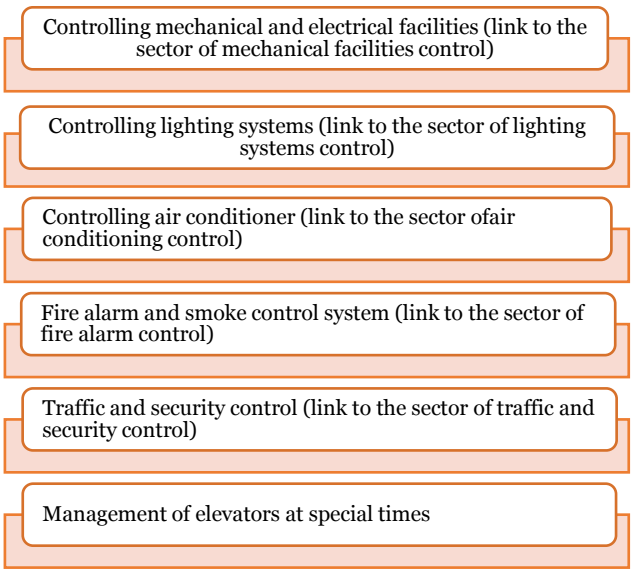

Figure 2. Tasksof Smart Management System of Buildings [6].

Benefits of smart buildings

Using the latest technologies, smart management system of buildings aimsat providing ideal conditions along with efficient use of energyin buildings. Four following benefits can be critical reasons for using such system in buildings.

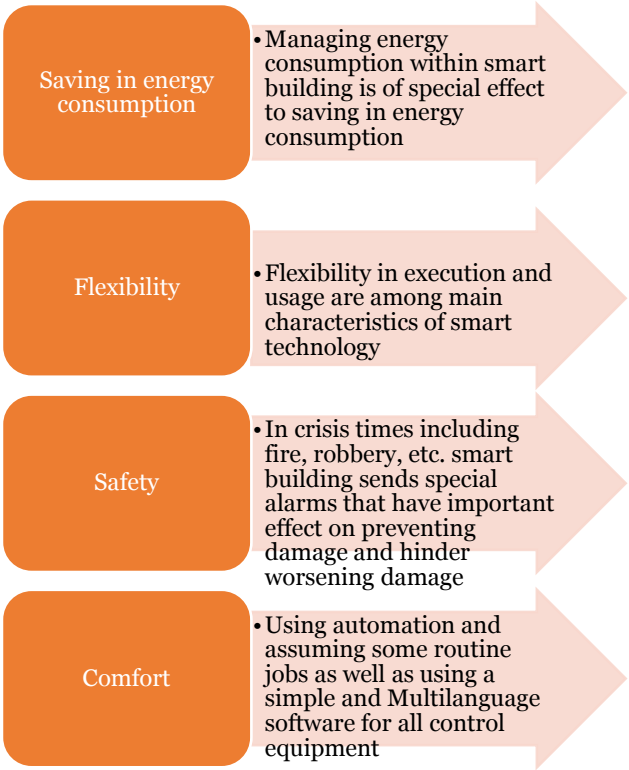

Figure 3: Benefits of Smart Buildings, [6].

Optimizing energy consumption

Until a few years before, energy saving was not so important and was not recognized by owners and investors in building sector. But after significant increase in consumption and awareness of worries regarding usage of energy and developments of cost-efficient technologies as to energy, benefits and efficiency of energy as a part of actual situation of managements and strategy regarding performances was considered. Such implications brought about formation of new horizons within construction sectors. Growing research experiences suggest that energy saving in heating and cooling sectors within public buildings accounts for 10 percent. Even while considering the fact that buildings used in this study had high rates of energy consumption, such rate is very significant [3].

Among very important benefits of smart buildings is energy saving. These buildings control all parts of construction with the least cost and with no involvement of human and save 30 to 40 percent of energy. Within a smart building with necessary facilities and equipment, it is possible to calculate the amount of energy based on consumption of fuel energy and electricity and use that toward lowering energy consumption and optimizing fuel consumption with in buildings. One of the alternatives toward saving energy, besides using smart management system of building, is using efficient construction material. Smart materials are in full interaction with the environment and are consistent with goals of sustainable development in architecture. Using smart materials and systems is of fundamental importance to saving energy consumption.

Smart materials and their role in optimizing energy consumption

New forms of today's buildings which are consistent with needs of today's people, are not just due to different design and indeed, manner of executing and type of materials used in buildings have role in making today's buildings different. Role of materials used in construction is of special importance because without materials, architecting is impossible. Also, materials represent rational principles as good as emotions in every design and in many technical specialties, provide a meaning for emotion inspiration.

Materials as the main elements of a structure, form foundation of that structure and give it life. In other words, materials make continuance of product's original form during its consumption period possible [7].

Smart materials are those materials that with their smart action against the environment changes can adapt themselves to environmental conditions just like living organisms. Some of these materials predict any kind of damage and failure in their structure and eliminate them. One or more quality of such materials such as form, hardness, frequency and color, significantly change in a controlled state or under the effect of electrical stimulation or magnetic fields. Progress process of these materials has started from structural and functional materials and proceeds toward creation of multifunctional materials which are superior to biological materials [8]. "Smart material" is a new term refereeing to materials and products enjoying the ability of comprehending and processing environmental events and appropriately reacting to them. In other words, such materials are flexible and can reversibly change their shape, color and internal energy in response to physical and chemical effects of the surrounding environment [9].

Classification of smart materials

In one categorization, smart materials are divided in to five classes:

Table 1: Classification of Smart Materials, [10]

Types of Smart Materials	Changes	Function
Shape shifter smart materials	-	-	This category of smart materials can change their internal properties and in response to external drivers, change their shape and dimensions. Such changes depend on distribution and configuration of internal changeable combinations. The most widely used types of these materials are temperature-reactive, piezoelectric, electro-reactive and chemo-reactive which currently are the focus points of architecture.
	Thermo strictive	Shape shifter temperature changes	Such smart materials as the sub category of shape shifting smart materials can react reversibly to changes in the temperature of surroundings. They encompass various kinds of expansive materials which enjoy thermal co efficient of expansion. The most important usage of these materials in architecture is in heating thermostats for services of building and as special stimulators in greenhouses and in facades for controlling and managing energy. Another usage of such materials is in air conditioning system. of rooms within buildings. Method of operation of such system is in a way that in specific temperatures, system becomes open or closed to provide suitable air conditioning.
	Piezoelectric		Second type of smart materials is piezoelectric materials.

			Formation of electrical current at both of their ends, changes their length. Using such materials, structures have been built that can be bent contracted or expanded by transmitting electrical current. such materials are widely used as sensors.
	Electro active Chemostrictive		
Colour changing materials	Photo chromic	Responsive to the intensity of light or colour change	Photo chromic materials (P.C.) react to light by changing their colour. Currently, photo chromic materials are available as photo chromic pigments, photo chromic glasses, photo chromic plastics and photo chromic polymers.
	Electro-chromic	Light change	Electro-chromic materials are those materials which using electrical current experience colour change or transparency. These materials might be the most suitable materials for energy control within buildings. Glasses made of such materials quickly change from transparent state into turbid and disperse light. They are controllable by user. Using electro-chromic materials in architecture is in electro-optical glasses. Electro-optical materials lose their visual characteristic, extent of transparency, when exposed to son rays.
Light-reflecting smart materials	LED	-	-
	Solar cells	-	Such systems integrate smart materials in a cover made of cells which turn solar light into electricity.
Energy-reserving smart materials	State-changing materials	-	Such materials can reserve energy which is evident or hidden in their bodies. For example, they can reserve energy in the form of light, heat, hydrogen or electricity. These materials are reversible. Therefore, they can reserve energy in different forms. The most widely used material in this category is state changing materials or P.C.M. These materials can adjust temperature inside the room as the medium of reserving coldness or hidden heat.
Smart materials capable of changing and exchanging internal constituents	-	-	Such materials have reversible constituents which can release or encapsulate materials in molecular form and as gas, liquid or solid or various physical or chemical processes. Performance of these materials makes them react when exposed to different gases, water vapour, water or even hydrous solutions or attaching them to their interior surface or adding them to their volume. Such materials are utilize din outer or inner facade of buildings and their most popular ones those that automatically get cleaned as well as those covers or layers which by locating on building surfaces, make pollutants in the air neutral and eliminate them. A type of waterproof material in this category is Intonate and a smart material known as self-cleansing material is titanium dioxide.

Types of smart glasses

Among the most important smart materials in constructing buildings is glass. During last three decades and after vast changes in glass industry in order to lower thermal loss and optimizing energy, using glass has become common more than ever. Such material significantly affects comfort and stability of the environment.

Table 2: Types of Smart Glasses [10].

Types of Smart Glasses	Function
Thermo-chromic	Without blocking light, blocks heat. In higher temperatures, can play the role of cover to change the state between absorption and reflectance of sun rays. That is, it makes usage of solar heating benefits in winter and reflectance in higher temperatures and avoidance of space high temperatures possible. However, in both cases, desired visual light is accessible for lighting purposes. Such glass reflects infrared from 29 centigrade degrees.
Electro-chromic	Glass unit attaches to electrical current using transparent films of 200 to 300 nanometre thickness with various colour intensity in spectrum of glass unit in order to change the extent of the desired transparency according to different quantities of thermal transmission. After current cut off, state change of lights maintained and there is no need to continuous current of electricity. When glass becomes turbid, thermal radiation is reduced and major part of passing rays is filtered in infrared spectrum.
Gaso-chromic	Gaso-chromic system is comprised of three main parts: One insulated gas-chromic glass unit, one reserve unit of gas and one control unit. Reserve gas unit is connected to the window in a closed hoop combination. This section is combined with building façade. A reserve gas unit can provide necessary gas for several gas-chromic modules (usually 10 square meters). Control unit provides manual and automatic adjustment of module and is placed in a desired part of room or connected to

	the control system of the building.
Liquid Crystal	These glasses are comprised of two glass parts (transparent or with undertone) and one interlayer film made of liquid crystal. Using quality of interlayer of liquid crystal, transparency or turbidity can be adjusted as desired. As these two glasses have the same amount of light transmission in both states of transparent and turbid, main usage of them is to partition interior spaces, although using them as anti-UV outer glass in glass working units of one or two layer is possible. Moreover, they can be used as video or slide displays as well.
Self-cleanser	Since the layer on the surface of the glass is photocatalyc (using light for reaction), they can eliminate connection between the existing pollutions on the surface of glass to glass. After setup, such glass must be exposed to sun for a few days to activate its special cover on the outer surface using UV (which is present even on cloudy days). After activation, thus layer can react with pollutions on the surface of glass and destroy their connection with the glass. After activation of the outer layer by solar rays, such glass maintains its special quality during night and in shade. Second quality of such cover which is activated along with photocatalyc quality by UV, is hydrophilic quality. Due to this quality, water on the surface of the glass is dispersed as a sheet. Therefore, this water is easily dispersed on the surface of the glass and cleanses it. Thus, even rain can clean surface of the glass. Such quality prevents formation of stains resulting from drying of water drops as well.

Investigating case studies of using smart materials in energy productivity of buildings

First smart building used technology in order to provide a safe, comfortable and energetic environment. In addition to energy saving, using smart materials in buildings, increases efficiency and provides for possibility of effective management according to special circumstances with the least expenses. In the following table, cases of using smart materials as to energy efficiency in buildings are offered.

Table 3. Investigating Case Studies of Using Smart Materials in Energy Productivity of Buildings, [11, 12, 13, 14]

Building	Function
Masdar City	 MasdarCity or Sustainable City is the title of the biggest architectural project within the area of bio-construction which is being constructed in UAE. This green city is located in one of the toughest environments in the world, in a desert near to AbuDhabi. It is supposed to be a micro-city free of any kind of pollution and carbon pollutants and compared to other similar cities, rate of water consumption in it will be reduced up to 60%. Beside all the sustainable urban development principles considered in designing such city, each and every one of its buildings must be sustainable and energy productive as well. For example, energy produced by the building of the institute is a lot more than energy consumed and excess of energy produced is transferred to AbuDhabi. Direction of streets and buildings makes maximum usage of natural wind for cooling possible. On the other hand, ceiling of all buildings is covered by canopy. Main electricity of the city is currently provided by ten-megawatt solar photovoltaic factory. Heating water consumed in this city is also done by solar radiation and various systems are used to refine and recycle waste water in the city. Entry of common automobiles in this city is forbidden and only electric cars are allowed in [11].  This project was conducted in Tokyo in 2004 and is the only sample in its kind in the world. This ten-storey structure includes 1300 square meter shopping centre, one concert hall and a restaurant. Interesting point in this project is its façade. In fact, 910 square meters of the facade in this 56 meter long building is visible and due to special designing system, this building is capable of demonstrating different

aspects during day and night [12].

Building of Commerce bank was designed by Norman Foster in 1992 as an approach to sustainable architecture. Among the most important characteristics of this structure is the attention paid to natural lighting and air conditioning. All the separate offices are lightened by the daylight and have windows with capability of smart closing and opening. These conditions make it possible to control internal characteristics of the building according to the weather conditions of the exterior area. This reduces the energy consumed to half the energy consumed in office buildings. In most parts of the year, natural air condition can be used as an alternative to maintain delightful air inside the buildings. If air condition systems can be mounted outside, natural air conditioning and cooling can reduce energy consumption and bring about required comfort [13].

Office Building Cambridge

This new headquarters for a biotechnology company is intended to allow the 920 employs and visitors to identify with the company. And combine functionality and flexibility with pleasant. Communicative working conditions and modern environmental technology. Stringent urban planning stipulations led to a restrained building envelope. Prefabricated, single-leaf curtain walls alternating with double leaf facades with accessible loggias as climate buffers and live spaces, windows that can be opened both manually and electrically for natural night-time ventilation, movable sun-shading elements and colour curtains combine energy-efficiency aspects with architectural and spatial differentiation [14].

CONCLUSION

Today, energy and optimizing its consumption within buildings is among the important issues in designing buildings. Considering the fact that major part of energy is consumed in building sector, using energy management systems brings about planning optimized energy consumption and saving and optimizing energy consumption. Using modern technologies and making buildings smartis away to enhance useful life of buildings, comfort of residents, saving in energy consumption and achieving sustainable development goals. Using modern smart systems and sensors, provides possibility of monitoring and controlling all areas under control through internet within buildings. That is, controlling lighting, thermal system, security and alarm systems, manual control of access to audio-visual and entertainment systems, air conditioning, weather filter and control. Using such systems reduces energy consumption within buildings and lowers costs of building maintenance. To this end, using smart materials as an in dispensable part of smart building which is in contact with the environment is necessary. Reducing energy consumption is among the key objectives of sustainable development and using smart management system of smart building and materials is a step toward achieving sustainable development.

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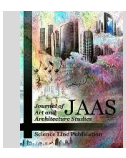

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