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Review article

Solar energy as a solution in sustainable architecture and intelligent buildings (case study: Ahvaz city)

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ABSTRACT

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The use of new energies is inevitable in line with sustainable development plans due to environmental pollution, global warming and the increasing use of fossil fuels. The use of fossil fuels is associated with greenhouse gas emissions and thereby global warming as well as secondary impacts such as desertification and dust storms in the Middle East including in Iran. The use of renewable energy is the best solution to avoid greenhouse gas emissions. Ahvaz City with a population of about 1338126 people and 3080.2 sunny hours per year is located in southwestern Iran. Ahvaz is among the best locations for application of solar systems. This is an analytical research carried out by desk study method. The present paper aims at evaluating the use of solar energy as a strategy for sustainable architecture and intelligent buildings in Ahvaz.

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1. Introduction

Today, the rational use of information and its application in the construction industry is a decisive factor in the development of large organizations, the business world and our individual lives. On the other hand, the energy

and reduced fossil fuels are among very important problems leading to many difficulties in the modern world. Given the critical and undeniable role of buildings in energy consumption and energy loss, the use of new technologies to reduce consumption of irreversible energies and to store sustainable energy are among major topics (Rucker, 2012, 3) in the sustainable architecture. The rapid development and widespread applications of information technology and communications resulted in a variety of applications in all aspects of human life.

The rapid growth of information technology develops systems that can measure and estimate changes to react against them. The progress in change management and design methods may improve physical environmental conditions. This transformation is more evident in work places. As a result, we are seeing tremendous growth in the field of designing intelligent buildings. In such buildings, the integrated information technology and communications systems will result in more comfort, safety and savings, especially in energy consumption.

2. Solar Systems

A) Photobiology system: in this system the photosynthesis is carried out in plants. Plants absorb solar radiation to convert carbon dioxide and water into saccharides.

B) Chemical system: in this system the solar radiation is used in chemical reactions. In some cases, the solar heat is utilized as a heat source in chemical reactions.

C) Photovoltaic system: in this system the solar energy is converted to electrical energy without the use of mobile and chemical mechanisms. This is called the photovoltaic effect.

D) Heating and cooling systems include hot water supply systems, heating and cooling of buildings, fresh water supply, transport and pumping systems, green space (greenhouse), solar dryers and ovens, refrigeration systems, power towers, solar dryers and solar power plants. Solar thermal systems are high performance and reliable. They can be used in different conditions to supply hot water in residential, commercial and industrial buildings. The potential use of this technology and its associated environmental benefits are considerable (James & James, 2005).

3. The use of solar energy in heating and cooling of buildings

The buildings receive solar energy through passive (or static) and active absorption. In passive system, the architectural design of the building is dependent on absorption and storage of solar energy. In this system, the building is naturally heated by the sun without the need for fossil fuels or other fuels. In the active method, the solar collectors and other energy resources should be used to supply and transfer the heated fluid to the building.

4. The design of a building with a passive solar system

Passive solar energy plays an important role in this strategy. In addition to reducing heating and cooling costs, the passive solar design provides residents with comfort, durability, attractiveness and environmental versatility. The main objective of the environmental versatile design is the efficient use of solar renewable energy with low risk of maintenance throughout the building lifetime. The passive solar design is capable of reducing heating and cooling costs while increasing spatial vitality and comfort. The following items will be clearly visible in a solar house built with correct principles.

1- Comfort: the solar homes are warm in winter and cool in summer. 2- Economics: home owners receive excellent return on capital. 3- Durability and stability: solar homes are usually made of materials with long life and low maintenance cost. 4- Attractiveness: solar homes are full of light and are very well connected with outdoors. 5- Environmental versatility: solar homes allow the efficient use of energy resources (Shaghayeghi and Maddah, 2012, 34).

5. Sustainable development

It seems that "sustainable development" is among the clearest terms expressing what occupies the minds of a lot of people. Accordingly, this term has a widespread and general applicability (Bronman, 1996). By definition, development means constant transformation over the centuries, especially in the economic, social and technical aspects of human civilization. Development is a right which must equally cover the current and future generations.

Sustainable development is the development that does not strike a danger to the environment and its advance does not require the destruction of global wealth and basic resources. Human is the center of attention in sustainable development so that human deserves a life full of health and development in harmony with nature. Such development requires a major positive fundamental change in the global economy, the rational utilization of natural resources as well as a fundamental shift in human attitudes to nature and serious revision of the production and consumption patterns.

6. What is an Intelligent Building?

Building Management System (BMS) refers to hardware and software installed for integrated monitoring and management of crucial parts of a building. BMS monitors different parts of the building to maintain the performance of various components of a building in optimal conditions to reduce unintended energy consumption and create a safe and pleasant environment. BMS allows the management and control of the building through automatic lighting control, traffic control (inputs and outputs), controlled heating and cooling, alarm and fire fighting, powerhouse control and logic communications between these systems.

7. The goals of an intelligent building

The goals pursued with implementing BMS in buildings include optimizing and saving energy, creating a pleasant environment for building occupants, permanent monitoring of all building components, building management during disasters, the efficient use of equipment and durability, reduced maintenance costs, detailed statistical reports from different parts of the building to optimize the consumption and performance and accurate record of the operation of various parts of the building, intelligent prioritization of energy consumption during the emergency.

8. The features and elements of intelligent buildings to control the environmental conditions

1- Building Management System: BMS is the brain of an intelligent building which is responsible for the management of various parts. BMS is a central processor which receives all information from different sensors to control and determine the appropriate response for intelligent elements (Wigginton, 2002). As mentioned repeatedly, the main purpose of BMS is energy storage and accurate and efficient use of resources. In addition to energy storage, this will result in return on initial investment expended for implementation of BMS (IRAN Beams).

2- Learning ability: Intelligent buildings are able to learn and predict the weather conditions to calculate the heating, lighting and etc.

3- Weather data receivers in intelligent systems are able to collect information about the indoor and outdoor environmental conditions (Wigginton, 2002).

4- The system is responsive to artificial lights. This system is able to detect the adequate light to turn artificial light off and vice versa.

5- Sunlight controllers: the sunlight controllers are used to receive and store energy in many cases. Intelligent systems in such buildings control and regulate the direction and position of the receivers.

6- Manual controllers: the manual setting and control by the residents and users of intelligent buildings is among important issues. The manual regulators and controllers are necessary in emergency situations or in the cases where there is a need for change (Wigginton, 2002).

7- Air conditioners: automatic air conditioners are used in intelligent buildings because of their improved performance. Moving elements in the intelligent buildings can be opened or closed for proper ventilation in favorable or adverse weather conditions.

9. The components of intelligent buildings

1- System input which receives information by receivers. All parts of a intelligent building must be equipped with devices to receive information and enter into the control system. When we speak of intelligent architecture, the starting point should be the sensors. The sensors are tools that collect the indoor and outdoor information. The sensors installed in the building enable the systems to achieve a good understanding of the indoor conditions.

The sensors installed outside the building collect outdoor information at specific times. The sensors are divided into three categories including internal and external sensors.

Table 1

Sensor types.

Regulatory sensors	Air quality sensors	Surveillance sensors
Building system sensors	Temperature sensors	Surveillance cameras
Mechanical system sensors	Solar radiation sensors	Traffic sensors
	Air pressure sensors	Fire and smoke sensors
	Light sensors	Vibration and acceleration sensors
	Water and gas flow sensors	Motor sensors
	Indoor air sensors	
	Humidity sensors	

Sensors are the nerves of a building that can feel special circumstances to adopt suitable decisions according to indoor and outdoor conditions (IRAN Beams).

2 - Data processor software analyzes information received from various parts of the building. BMS controls the share of systems as a single system. In addition, BMS is able to control each system individually. The control center of the building is the place where all systems are integrated. Hence, this place is called building systems integrator (BSI).

To integrate different parts of the building, they should have known addresses to be recognized by other components.

3- The system output adopts the necessary measures in the face of information received by the input system after processing them. BMS outputs are orders issued based on the decisions adopted by the system. These decisions shape the control system responses. The responses can be divided into two categories including internal and external responses. Internal and external responses and commands are taken by the control system. The internal responses include all indoor actions.

The calculated and planned orders in the system are among these responses. Another example for the internal response is the ability of an intelligent structure to change its orientation. Through this, the structure can resist against wind pressure. External responses are the outcomes of internal responses based on processed data. An external response can be static or dynamic. External static responses include changes in temperature, visual, sound and light changes. On the other hand, the dynamic responses are in the form of motion. For example, when the system decides when the door is opened or closed, this is a dynamic response provided by the responsive architecture (IRAN Beams).

The sun is the source of various energies in the nature such as underground fossil fuels, wind energy and plants used by most creatures, organic materials that can be converted into thermal and mechanical energy, waves and tidal power caused by gravity and motion of moon around the sun. These are all symbols of the sun's energy. The sun is one of two major sources of energy that must be used, because it does not require advanced and costly technology. It may serve as a useful resource of energy in most parts of the world.

Unlike some energies like nuclear energy, the solar energy is not dangerous and is not associated with adverse effects. The solar energy is the best way to achieve energy and economic development for countries lacking the underground resources. Today, the solar energy is extensively used. However, the economic possibilities of different designs must be calculated precisely. Technologically, the solar energy can be used to heat homes. Economically, researchers and scientists are further encouraged to use solar energy due to the increasing rate of fossil fuels and other energy resources as well as cost-cutting efforts.

Due to the geographical situation of Iran, the grounds for self-sufficiency in energy are available. The use of solar energy could also pave the way for job opportunities in many fields including material production, equipment construction, transportation systems and other relevant fields. The solar energy not only needs semi-skilled labor, but it will provide jobs for professionals. The use of solar energy is an effective step for reducing (or eliminating) the use of fossil energy in the building and thereby reduced pollution.

10. The benefits of solar energy

The solar energy reduces the payback period. The clean solar energy provides an inexhaustible access while reducing the demand for fossil fuels and hydropower and reducing environmental barriers (Robertson and Athienitis, 2009: 2). The solar energy is more economical and more accessible to consumers than the electrical energy (Tiwari, 2006: 2).

11. The use of solar energy in ahvaz

Everyday life is dependent on the production and consumption of energy. Thus, the energy supply and demand in human societies are continually rising (Khoshakhlaq et al, 2005, 173). The rapid growth of global energy consumption resulted in adverse environmental effects in addition to difficulties in securing energy resources. In 2005, 27136.4 million tons of carbon dioxide was produced from burning combustible fuels throughout the world (Kabi-Nejad, 2006). Of this, 1671.1 tons of greenhouse gases were produced in the Middle East where 79% was CO₂ emissions. Of this, 1238.1 million tons were produced from burning combustible fuels.

Iran with a share of 36.14% is the largest contributor to the greenhouse gas emissions in the Middle East. Saudi Arabia and the UAE are in the next places with a share of 24.29% and 9.14%, respectively (IEA Website). The consumption of energy carriers severely threaten the environment due to pollution caused by greenhouse gas emissions in the conversion process and the destruction of the ozone layer leading to global warming and climate change (Khoshakhlaq et al, 2005, 173). Among the consequences of global warming are environmental problems and increased natural disasters such as hurricanes and tornadoes, severe fires in forests, tides and horizontal movement of sea water, floods, famine and drought and insect infestation which have increased in recent decades.

The adverse effects of global warming in the Middle East appeared as drought as well as a marked increase in air pollution due to dust storms and drying of wetlands and lakes in recent years (Daftarian, 2009, 56-57). Accordingly, one of the ways to deal with energy and environmental crises of the present century is to replace fossil fuels with renewable energies including solar energy. According to available statistics, 13.3% of energy in 2005 has been supplied from a variety of renewable energy resources. The share of solar energy was 0.29% (the Renewable Energy Organization of Iran).

Among the solar energy applications are power plant applications. The solar energy can also be used for solar water heaters and showers, solar heating and cooling, solar water sweetener, solar dryers, solar cookers, solar ovens and solar homes (Renewable Energy Organization of Iran). Cooling, heating and hot water include about 60% of total energy consumption in the buildings. Of this, about 22% of the total energy consumption is consumed for water heating worldwide. This is a significant amount. Much of the energy needed for heating purposes can be provided with the use of solar water heaters.

The use of solar energy to provide hot water in homes and industrial centers is one of the most cost-effective and applicable methods to use renewable energy in the today's world. This is why most developed and developing countries are investing massively in this field (Eyvazi, 2003). Until 2005, more than 150,000,000 m² equivalent to 92.7 GWh heating collectors were installed throughout the world. The collectors installed in 2005 increased by approximately 130% as compared to 2003. The largest producers of heating collectors are China, USA, Japan and Turkey. Almost more than 90% growth in the use of heating collectors occurs in China (Noor Portal).

Currently, 200 million people are using solar water heaters in China (Peyman, 2004, 16-19). The Department of Energy installed 1041 solar water heaters in Iran until 2006. Oil Ministry installed a total of 16,854 solar water heaters and 419 solar showers during 2001-2008. Given the growing importance of solar energy in providing hot water, numerous studies have been conducted in this field in recent years. Ahvaz City with an area of about 8136 km² and a population of about 1338126 people is located in the center of Khuzestan province in southwestern Iran (Khuzestan Statistics, 2007). Ahvaz has a high potential for utilizing solar energy systems, especially solar water heaters due to daily radiant energy rate of 19.56 MJ/m², total 3088.2 sunny hours, sky clearness index of higher than 0.64 and average transparency index of higher than 0.76.

12. Conclusions

Solar energy is an inexhaustible energy which is easily accessible. In addition, it can be used with minimal cost. The total daily amount of radiant energy in Ahvaz is 19.56 MJ/m². On the other hand, the total amount of sunny hours is 3238.94 h/yr with sky clearness index of higher than 0.64 and average transparency index of 0.76.

Accordingly, Ahvaz is in good condition in terms of solar energy radiation. Economically affordable solar buildings are durable, comfort, attractive with minimal maintenance costs. An important step is taken towards sustainable development and getting away from dependence on fossil fuels with the use of solar buildings.

Solar energy is clean and does not produce pollution like fossil fuels. Although the purchase and installation of solar systems are costly and elimination of subsidies are among the main objectives of the government, the allocation of more subsidies to this sector is justified. The use of such systems enhances the energy safety while interdependence of a single type of energy.

13. Solutions and suggestions

The major consumers of energy carriers have followed quite serious and planned activities and policies to reduce energy losses caused by the consumption of energy carriers and optimizing fuel consumption for more than three decades. Through this, they not only attained considerable savings in the cost, but they effectively prevented the increasing trends of environmental degradation. Enhanced manufacturing technology and increased government revenues from taxes controlling fuel consumption are among other benefits of energy policies.

To reduce greenhouse gases and protect environment and energy resources, all organizations and community groups in Iran including building, transport and industrial sectors should be actively involved. Guidelines and recommendations in this regard are given below:

1 –The major problem that increases the cost of solar systems is the lack of local production technology, equipment and high initial cost. To solve this problem, technology transfer and the design and construction of the prototypes can be considered.

2- Although the purchase and installation of solar systems are costly and elimination of subsidies are among the main objectives of the government, the allocation of more subsidies to this sector is justified. The use of such systems enhances the energy safety while interdependence of a single type of energy.

3- The real price of energy should be provided to consumers instead of subsidizing for each MJ of energy to encourage people to save energy. Subsidies should be allocated to use solar energy for heating needs.

4- The allocation of long-term loans with low interest for consumers and manufacturers of solar water heaters and giving subsidies to consumers.

5- Promoting the use of new energy systems. Familiarizing people with modern methods of optimizing the energy consumption through the mass media, compulsory courses in energy management in all engineering disciplines, assigning some sections of textbooks to energy consumption optimization and introduction to renewable energies, educational animations and films to introduce the benefits of new energies such as solar energy, preparation of educational tracts, pamphlets and educational posters on renewable energies, painting, essay writing and wall papers competitions on renewable energies in schools and naming a day of the year as clean energies.

5- Rising public sensitivity to air pollution caused by fossil fuels due to their direct and social costs on human health as well as the long term adverse effects of air pollution in normal people.

6- Further studies are recommended to investigate the economic and environmental benefits of other solar energy systems.

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