

A review on optimized control systems for building energy and comfort management of smart sustainable buildings

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ABSTRACT

Buildings all around the world consume a significant amount of energy, which is more or less one-third of the total primary energy resources. This has raised concerns over energy supplies, rapid energy resource depletion, rising building service demands, improved comfort life styles along with the increased time spent in buildings; consequently, this has shown a rising energy demand in the near future. However, contemporary buildings' energy efficiency has been fast tracked solution to cope/limit the rising energy demand of this sector. Building energy efficiency has turned out to be a multi-faceted problem, when provided with the limitation for the satisfaction of the indoor comfort index. However, the comfort level for occupants and their behavior have a significant effect on the energy consumption pattern. It is generally perceived that energy unaware activities can also add one-third to the building's energy performance. Researchers and investigators have been working with this issue for over a decade; yet it remains a challenge. This review paper presents a comprehensive and significant research conducted on state-of-the-art intelligent control systems for energy and comfort management in smart energy buildings (SEB's). It also aims at providing a building research community for better understanding and up-to-date knowledge for energy and comfort related trends and future directions. The main table summarizes 121 works closely related to the mentioned issue. Key areas focused on include comfort parameters, control systems, intelligent computational methods, simulation tools, occupants' behavior and preferences, building types, supply source considerations and countries research interest in this sector. Trends for future developments and existing research in this area have been broadly studied and depicted in a graphical layout. In addition, prospective future advancements and gaps have also been discussed comprehensively.

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1. Introduction

1.1. Building energy scenario

The world's predominant fossil resources are at the verge of depletion due to the enormous usage of energy resources in the last two decades. Therefore, concerns over changing climatic conditions (i.e. global warming, depletion of ozone layer, etc.), energy security, and adverse environmental effects are growing among governments, researchers, policy makers, and scientists in developed as well as developing countries. The International Energy Agency (IEA), in regard to the current energy scenario, has raised the concerns for environment, energy security and the economic prosperity generally known as (3Es) [1]. However, the European union (EU) describes energy-cut objectives until 2020 [2]: (i) the EU GHG emissions reduction should be at least 20% below the levels of 1990, (ii) renewable energy contribution of a minimum 20% in the energy consumption of EU and (iii) primary energy usage would be reduced to 20% in comparison to anticipated levels through energy efficiency measures. Moreover, almost like targets and even much restricting in some cases have been specified by the US policy of energy efficiency and conservation [3].

Globally, the challenge of the growing energy demand in buildings is mysterious. Buildings account for more than one-third of the total primary energy supply. The building energy consumption in selected countries is shown in Fig. 1. Since, 40% of the world's energy is being consumed in buildings ultimately, it accounts for 30% of the CO₂ emissions, as given in Table 1. The CO₂ emissions of some selected countries available in the literature indicate that the USA being the largest emits approx. 40–48%. On an average, the potential savings of approximately 30% could be achieved as in Table 1 through the intelligent automation in buildings. In context to that, the World Business Council for Sustainable Development (WBCSD) in 2009 conducted a research that found that the energy usage in buildings could be cut dramatically providing a saving of as much as the entire transport sector uses currently [4].

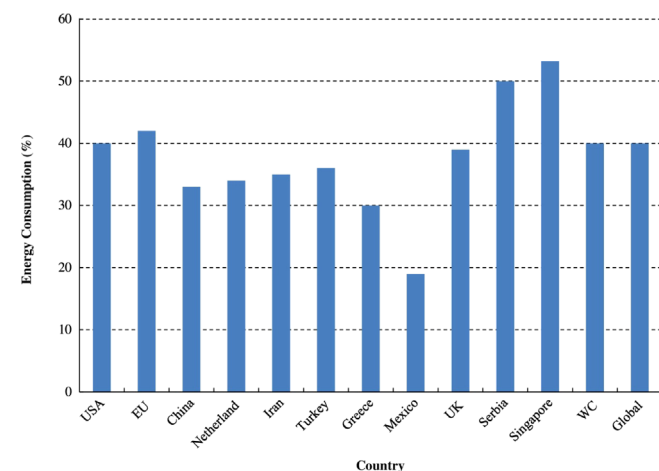


Fig. 1. Building energy consumption in selected countries.

Therefore, the saving of building energy consumption and wastage is significant, since, it helps to preserve the finite fossil resources, lower the energy cost for consumers and business, thus allows building sustainability. Besides, the contribution of renewable resources in buildings is likely to be constrained due to various limitations. In such circumstances, efficient management of building energy plays a vital role to achieve a low carbon economy and sustainability possibly at a faster rate. Energy efficient buildings, which facilitate intelligent building control, are becoming the trend for the future generation of buildings.

1.2. Indoor building comfort

Buildings are generally built for human's habitation. Moreover, approx. 90% of people spend most of their time in buildings [5]. Indoor comfort plays a significant role and poses a huge impact to preserve inhabitant's health, morale, working efficiency, productivity and satisfaction [6]. There has been an increasing demand by inhabitants for the improvement of indoor environmental comfort, whilst reducing energy consumption and CO₂ emissions during the previous decade.

Therefore, an energy and comfort management system (ECMS) must be comprising intelligent control systems for buildings, which uses computers, microprocessors, storage devices and communication links [7]. The main aim of an ECMS is to fulfill the occupant's expected comfort index whilst reducing energy consumption with regard to the energy price variation during the operation of building. ECMS commonly requires functions including indoor comfort parameters (classified in multiple categories and the most significant are thermal, humidity, indoor air quality and illumination levels), occupant preference and electrical energy control. Ensuring the comfort index, generally defined as the condition of the mind, which articulates satisfaction of environmental conditions, is due to human psychological effects. In various cases, people may decline to work or live in a particular

Table 1

Building energy consumption and GHG emission with saving potential in selected countries and world.

Sr. #	Country/region	Building energy consumption (%)	CO ₂ emissions (%)	Potential saving (%)	Reference
1	USA	40	40–48	20	[24,39,40,54]
2	European Union	40–42	35–40	27–30	[25–27,41]
3	China	33	–	–	[28–30]
4	Netherlands	34	–	–	[61]
5	Iran	35	–	–	[31]
6	Turkey	36	32	30	[32,33]
7	Greece	30	40	–	[34]
8	Mexico	19	–	–	[118]
9	United Kingdom	39	–	–	[35]
10	Serbia	50	–	20	[36,37]
11	Singapore	53.2	21.4	–	[42,229]
11	Western countries	40	–	–	[38]
12	Global	40	30	5–30	[22,23]

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