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Smart innovation systems for indoor environmental quality (IEQ)

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ABSTRACT

This work explores the application of a real-time monitoring system to achieve optimal indoor environmental quality (IEQ). It focuses on information and communication technology (ICT) applications and building information modeling (BIM) through a case study from an architect point of view. ICT-related applications have drawn attention from smart buildings as potential means of providing correlations between users and building systems to improve energy efficiency and comfort. This work attempts to present the main progress in the fields of energy efficiency and energy management strategies through a cost-effective ICT application. In order to investigate whether users can take advantage of natural environmental factors during occupied hours in office buildings, daylight and energy performance simulations were carried out. This work explores users as the primary factors to improve indoor environmental quality (IEQ) and energy efficiency. The results support the use of real-time monitoring systems in office buildings. It seems, however, that there is a need for individual user control of thermal, ventilation, and lighting.

1. Introduction

Rising energy costs and consumption in recent years, especially in buildings, have led researchers to consider new methods and approaches for reducing energy use. The building sector accounts for about 40% of total energy consumption and 38% of the CO_2 emissions in the U.S. [1] and the commercial and residential building sector account for 38.7% of the total energy consumption in Europe [2]. Energy efficiency in buildings nowadays has become a prime objective for energy policy at regional, national, and international levels [3].

Information and communications technology (ICT) and digital transmission of data have changed sustainable development methods and principles. In a study by Hilty and Ruddy [4] the role of ICT in sustainable development was discussed. Their hypothesis was founded on the "Brundtland definition," the definition of sustainable development as that which meets the needs of the present without compromising the ability of future generations to meet their own needs (World Commission on Environment and Development 1987). They pointed out that the normative implications of the Brundtland definition, if taken seriously, have been underestimated in the discussion of sustainable development during the last two decades and that this underestimation (among other negative consequences) leads to a misconception of the role of information and communication technologies (ICTs) in sustainable development. Furthermore, in their study two points of view techno-optimistic and techno-pessimistic were discussed. The currently prevailing misconceptions distorting the role of ICTs in sustainable development is a "techno-optimistic" view expressed by the documents produced at the World Summit on the Information Society (WSIS) and a "techno- pessimistic" view expressed by some scholars as an antithesis to the WSIS position. From techno-pessimistic point of view, ICT development could result in pollution and unsustainable structure.

Although ICT applications are still assumed to involve complex arrangement of devices that cannot be easily controlled, they have opened up new possibilities for user interactions with the surrounding environment. Furthermore, they can fruitfully contribute to move towards more sustainable development and improve spatial and functional qualities of the built environment. For example, ICT based systems have the significant role in energy efficiency and HVAC services [5]. Their study presented control and monitoring strategies to reduce energy consumptions for lighting and air conditioning through both wired and wireless sensor networks.

It is clear that current smart approaches and specific ICT-related applications such as sensors, mobile technologies, networks, big data, etc. can achieve sustainable development goals with physical intervention in the natural environment. A generic description of relevant ICT applications and their impacts on sustainability improvements links together ICT applications, smart objects, and sustainable design objectives (Fig. 1). ICT applications

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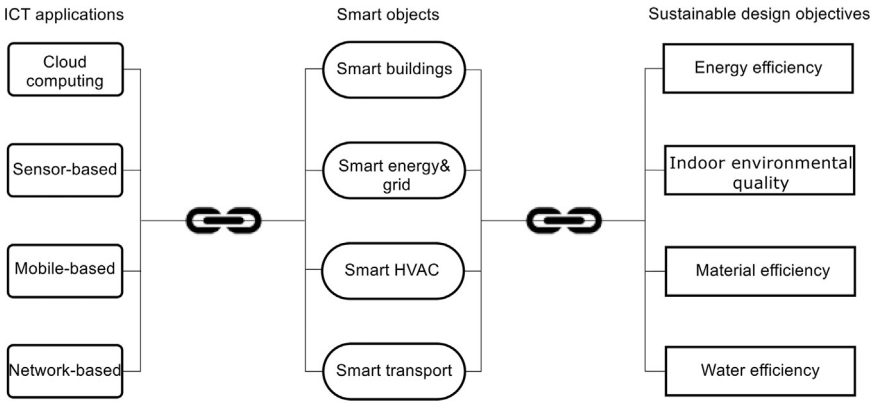

Fig. 1. Relevant examples of ICT applications and improved results.

can provide key contributions to smart and sustainable growth.

There are many initiatives with methods and devices to leverage ICTs for smart sustainable cities and buildings. For example, the eeRegio Wiki is a resource for local, regional and national authorities (cities, municipalities and regions) throughout Europe. The Wiki and forum provide an extensive body of practical advice and examples of good practice in the planning and implementation of energy efficiency initiatives involving ICT [6].

Although ICTs may have side effects associated with energy consumption and incompatible materials, they play significant roles in enabling energy efficiency services in buildings. In order to understand better the impacts of ICTs on sustainable development, it is necessary to compare two main types of direct and indirect effects. As mentioned in the previous sections, ICTs have made major positive impacts to many areas of the built environment including smart buildings, grids, smart transport, etc. Therefore, a life-cycle analysis may be useful to address potential effects of ICT applications on sustainable development and climate change adaptation.

According to SMART 2020 [7], report published by the Global e-Sustainability Initiative report (GeSI), ICT technology can lead to emissions reductions from main sectors such as buildings, transport, industry and power (Fig. 2). It can be concluded that ICTs should be investigated in depth from climate change mitigation and sustainability goals perspectives. In order to enhance operational efficiency among ICTs, it is necessary to use methods based on key dimensions of sustainable development such as environmental, economic and social. A series of sustainability action plans and targets should be taken into account for the adoption of ICTs and digital technologies prior to launching applications. According to Mitchell [8], there are five main opportunities such as dematerialization, demobilization, mass customization, intelligent operation and soft transformation for ICTs to make cities and buildings more environmentally sustainable. In the field of intelligent operation, ICTs have potential roles in facilitating energy management in buildings and cities. They can provide pathways to lower energy use through advanced monitoring. Furthermore, the use of ICT applications can help users to better understand and manage energy consumption.

It is worth noting that ICTs have a direct impact on user behavior and awareness. The end-user behavior is one of the most important factors for achieving positive systemic outcomes relevant to the use of ICTs in the built environment.

Recent development and technologies in the domain of architecture, engineering and construction, have led to the emergence of so-called smart buildings and cities. Smart buildings are defined as buildings that should be sustainable, healthy, technologically aware, meet the needs of occupants and business, flexible and adaptable to deal with change [9]. The word “intelligent” was first used at the beginning of the 1980s to describe buildings, together

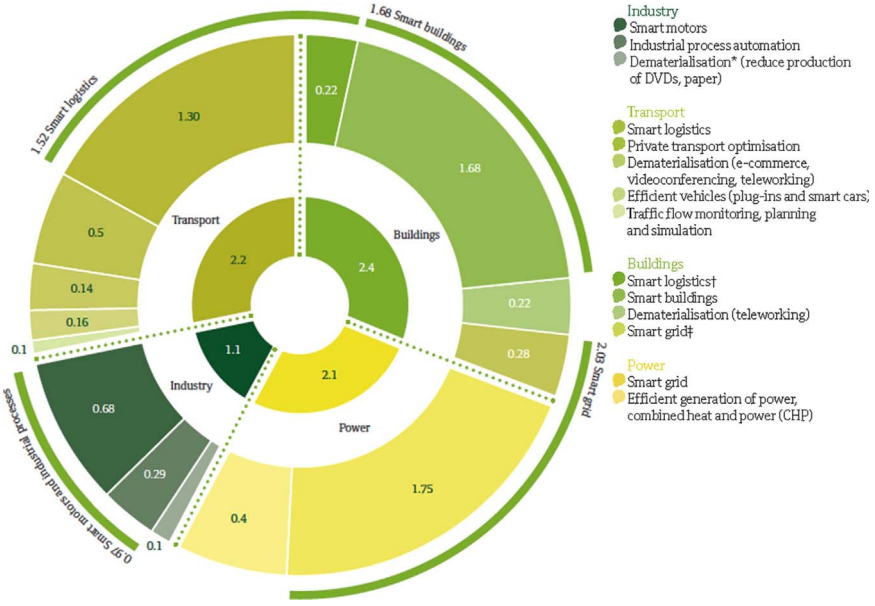

Fig. 2. The enabling effects of ICTs: Reducing GHG emissions by 2020 [7].