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Information and Communications Technologies (ICTs) for energy efficiency in buildings: Review and analysis of results from EU pilot projects

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ABSTRACT

Information and Communications Technologies (ICTs) can play a potential role in improving the energy performance of buildings by the implementation of effective solutions that take advantage of the energy interactions between all the elements included in a building.

A revision of the 105 pilots implemented or under implementation in 18 projects in the area of ICTs for energy efficiency in buildings located in 23 European countries, through 88 cities with different types of climates, buildings and technologies have been carried out through documentary and field analysis of the energy, economic and social project results. These results have been extrapolated to assess the potential energy savings which could be expected at the EU level by implementing the solutions proposed by the projects.

By the implementation of the different ICT solutions, buildings have achieved more than 20% energy savings. Pilots have demonstrated that the effectiveness of the ICT solution does not depend directly on the different climates where the solutions are implemented, but on several factors, such as the level of motivation, perceived thermal comfort, quality of social interaction and communication and ICT support.

1. Introduction

The European Commission has recognized the potential role Information and Communications Technologies (ICTs) can play in improving the energy performance of buildings in several high-level policy documents [1–4]. ICT and ICT-based innovations may provide one of the potentially most cost-effective means for Member States to achieve the 2020 target and are key to deliver the fundamental yet urgent changes required in local and regional communities.

ICT solutions for energy management and resources integration should be considered in order to help designers, stakeholders and users to increase the energy efficiency of those individual systems and the overall efficiency of the European buildings [5]. ICT solutions are very helpful to:

- Verify whether the building and the systems installed behave as designed.
- Monitor that the performance and energy efficiency are stable during the life time of the building and do not decrease.
- Achieve more energy savings combining the operation of the different systems in the building.
- Provide feedback to change user's behaviour and install new energy efficient technologies or fine tune those already installed.
- Help to increase users' comfort.

The Commission is co-financing projects and horizontal actions to support the development and deployment of energy efficient solutions for buildings under the 7th Framework Programme for Research and the ICT Policy Support Programme (ICT PSP) which is the part of the Competitiveness and Innovation Programme (CIP) focusing on ICT, with the aim of demonstrating the energy efficiency benefits ICT can bring to building owners and their inhabitants/users.

Projects covering residential and non-residential buildings (including social housing and public buildings) have built common methodologies to calculate energy savings via ICT and the results are showing significant reductions in energy consumption and CO_2 emissions of up to 20%.

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Nomenclature

ANN	Artificial Neural Network
BMS	Building Management System
CCTV	Closed-Circuit Television
DHW	Domestic Hot Water
EAS	Energy Awareness Services
EMS	Energy Management Services
GA	Genetic Algorithm
HPC	High Performance Computing
HVAC	Heating, Ventilation and Air Conditioning
ICT	Information and Communication Technology
IPMVP	International performance measurement and verification protocol
REEB	The European Strategic Research Roadmap to ICT enabled Energy-Efficiency in Building and Construction
RMS	Resource Management Services
ROI	Return Of Investment
RUAS	Resource Use Awareness Services
SCADA	Supervisory Control and Data Acquisition
SEP	Smart Energy Platform
SME	Small and Medium-Sized Enterprise
SSL	Solid State Lamps
STP	Sewage Treatment Plan
TCP/IP	Transmission Control Protocol and the Internet Protocol
VLC/PLC	Visible Light Communications and Powerline Communications
WTP	Water Treatment Plan

Two common methodologies [6,7] for energy efficiency measurement developed by CIP social housing and public buildings projects have been designed to collect in a more harmonised way the appropriate data and produce a more meaningful quantitative analysis of the energy savings potential of ICT solutions in residential and non-residential buildings.

This analysis of results from EU pilot projects provides a comparative overview of various ICT solutions to achieve energy savings in buildings (public buildings and social housing) which were piloted under the CIP ICT-PSP. The objective of this study is to analyse energy usage data generated by a set of projects piloting various types of ICT systems/gadgets to reduce energy consumption in buildings (see Table 1). All projects collected the data, using the designed methodologies over a period of one year, in buildings with and without (baseline) energy saving systems/gadgets.

2. State of the art

The state of the art of ICT systems for energy management at building level is discussed, focusing on the fundamental fields in which R&D has to assume a huge challenge to start shifting the traditional and at the same time high-rigid energy management model. Five key areas including design and simulation tools, interoperability/standards, building automation, smart metering and user awareness tools have been identified [8], where there is potential to improve energy efficiency through the use of ICTs, and they are considered as the next ICT generation for future smart buildings.

According to REEB 2010 (The European Strategic Research Roadmap to ICT enabled Energy-Efficiency in Building and Construction), ICT systems have been identified as one possible means to design, optimise, regulate and control energy use within existing and future (smart) buildings. ICTs could not only be used for decreasing energy in buildings, but also to create new business opportunities driven by the need for energy efficiency. Throughout the life cycle of a building, most energy (~80%) is used during the operational stage [9]. The decisions made in the early design stages or in renovation stages for existing buildings thus influence about 80% of the total life cycle energy usage, while the impact of user behaviour and real-time control is in the range of 20% [9]. Therefore, there is an urgent need to find new possibilities to decrease the energy usage in buildings [10], for example through effective energy management of the facilities installed, such as chiller systems [11] and HVAC systems [12], especially in office buildings.

ICTs can lead to reductions on a global basis five times the size of the ICT sector's own emissions, which is 15% of total global emissions in a 'business as usual' scenario for 2020 [6]. One of the greatest roles that ICTs could play is in better design, management and automation of buildings. Industries and governments alike must find ways to utilise the possibilities.

The Building Management System (BMS) market is changing rapidly [13,14]. Technological advances in building monitoring and control are opening the way to an era of huge volumes of data on building energy use and efficiency. Vendors are discovering innovative methods to capitalize this information to help buildings operate more efficiently. Although there has been a focus on energy efficiency in commercial buildings for some years, the BMS market can still be considered nascent. The landscape of new entrants, new technologies and new methodologies is expanding rapidly, and even well-established market leaders are finding new ways to present and promote their businesses.

2.1. *Optimisation approaches through ICTs for Energy Efficient Buildings*

Significant research efforts have been recently directed towards building energy optimisation through simulation with the objective of reducing buildings' energy consumption. For example, a recent study [15] shows a High Performance Computing (HPC) based cloud model to study and optimise the energy consumption in buildings through *EnergyPlus* simulation-based optimisation. To this end, the study considers several factors such as performance, cost and user perspectives, compares two different environments, determining their effectiveness to support simulation based optimisation and identifies their limiting factors through detailed performance analysis [15].

In this line, another study [16] presents a web-based parallel Genetic Algorithm (GA) optimisation framework based on distributed high-throughput computation environment (parallel NSGA-II), with which it is possible to reduce the computational time of complex buildings' energy optimization problems. This optimization framework was then tested in an experimental building in Bilbao (Spain), through its implementation in *EnergyPlus*, achieving a reduction in the building's energy consumption of about 15% while significantly reducing the computational time (the parallel NSGA-II was around 39 times faster than a single process GA) [16].

On the other hand, other studies, such as [17–19], focus on reducing the gap between predicted and actual energy consumption in buildings through ICTs to predict and optimise the buildings' energy consumption. In particular, Yuce and Rezgui [17] developed an Artificial Neural Network (ANN) to learn energy consumption patterns and behaviour within the building, which can then be used as the cost function of a Genetic Algorithm (GA)-based optimization tool to generate optimized energy saving rules considering multiple objectives and constraints. This solution developed was then tested on both simulation platform and a pilot building located in the Netherlands, achieving an average of 25% energy reduction while meeting occupants' comfort conditions [17]. In this line, Yuce et al. [18] utilised an ANN based prediction approach to predict the energy consumption and thermal comfort level of an indoor