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Intelligent buildings for energy consumption management

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Abstract. The main concern of the paper is the energy consumption management, in relation to the advantages and disadvantages of an intelligent building. The building sector consumes about one third of primary energy. An intelligent use of energy could have an impact on the energy consumption and cost. Energy management is the process of controlling, conserving and monitoring the energy in a building or recently in a home. With the use of sensors, all systems are connected and useful data is gathered to improve the building's efficiency. Intelligent building design is the future of building and building services sector. Enhancing energy preservation strategies and using sustainable design approaches are necessary in developing intelligent buildings. This implies a more effective approach to reaching the green goals, and it also implies financial savings. Building an intelligent building involves a larger investment, but in the long run the usual expenses will decrease. National grid energy consumption will decrease with the use of renewable energy sources, such as solar or wind energy, if the energy is produced on site. In order to make a difference in the climate change, intelligent buildings depend on the non-fossil sources, which will affect the energy usage. Furthermore, an intelligent building will increase the comfort and productivity of its occupants, for either a workspace or a home.

1. Introduction

Defining smart buildings has been done in countless ways, in connection with many topics, such as energy consumption, technology, equipment, user interaction [1], but a clear definition is given by the UK-based European Intelligent Building Group: an intelligent building 'creates an environment which maximizes the effectiveness of the building's occupants, while at the same time enabling efficient management of resources with minimum life-time costs of hardware and facilities' [2]. In this paper we analyze the advantages and disadvantages of the intelligent buildings regarding energy consumption and energy management.

As it is shown in figure 1, the households energy consumption represents almost one third of the final energy consumption in European Union, 2018. Nowadays, the goal is to have a building with minimal energy consumption and maximum comfort for the occupants. An intelligent building can decrease its energy consumption by integrating a building energy management system, which is a system that controls the occupants' energy needs. In order to make a difference in the building sector (and as a consequence, in the climate), intelligent buildings depend on the non-fossil energy sources.

The usual renewable energy sources are solar, wind, water (hydro), biomass and geothermal. The most used renewable energy sources in the intelligent building sector are solar, wind, and geothermal. Photovoltaic panels are a great way for the intelligent building to produce electricity, due to the fact that



they are easily installed on the roof, on the facades or in the nearby land. If mounted on the roof or on the facades, the PV panels take little to no usable space. The great advantage they have is that they usually do not require useful space. The geothermal energy is used for heating or cooling the space by using a heat pump. Heat pumps are a great option to produce thermal energy on the scene, and on the long run they are a way to save money regarding heating or cooling the spaces. The heat pumps are very popular, not only in the intelligent building sector, and their demand is constantly growing due to the advance of the technology. With the use of non-fossil energy sources (regarding on-site energy production), the energy consumption costs will decrease.

Furthermore, monitoring the energy consumption will have a positive impact over the energy consumption, while following the user's needs and by taking measures to control and to limit the energy consumption. Energy consumption monitoring can mean logging into an application to see if there are appliances that can be turned off or even programming them to work according to a preset schedule. For example, the heating or the cooling installation can be set up depending on the user's schedule. If the user has a classic 9 to 5 job, the heating/cooling installation can be set up to start one hour before the user will be back home. Therefore, there will be a minimal energy consumption while he is at work and also the comfort levels will be met by the time the user will be back home. This could be a use even in larger or public buildings, by setting up the heating/cooling installation to start right before the building program will start.

Beside the energy sources, the building's insulation is another important step to take into consideration, since the energy loss dictates the energy consumption. Insulating the building efficiently increases the energy efficiency. In order to keep the building green, more and more engineers choose to use bio-based insulation materials. The bio insulation is made out of animal or plant-based materials, they require less energy in the production process and also, they have a positive impact on the healthy indoor climate.

Furthermore, a thermal, auditory, natural light and natural ventilation comfort is given by double-skin facades. [3] Double-skin facades started to be a trend among office buildings and public buildings. Besides the modern look they give to the building, they keep up with the insulation standards for the heating and for the cooling seasons.

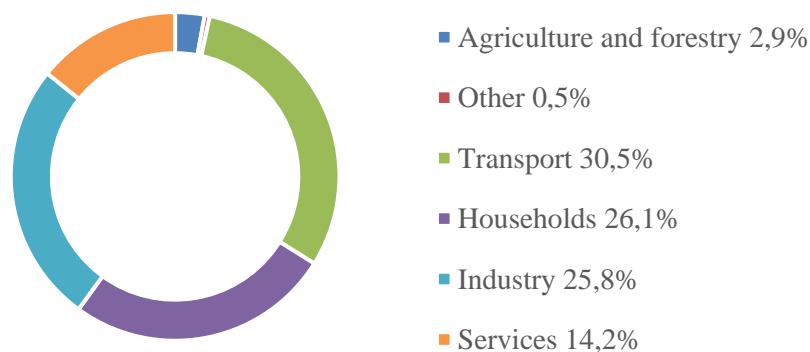


Figure 1. Final energy consumption, EU, 2018 [4].

2. Methods and procedures

This paper analyses the new concept of intelligent buildings and traces the link between comfort, smart systems and energy efficiency. An intelligent building allows its occupants to control the appliances and the energy consumption. The energy management system that every intelligent building has (even if it is an office building, a house or a commercial building) can control many aspects of the building, such as thermal comfort, lighting smart system or water supply. Designing a good management system for the building is crucial to keep track of the energy consumption. The user's comfort and the increasing need of energy in the household/work place will increase the energy consumption, but with a smart

configuration, the energy levels will be met and the energy consumption will decrease. This paper displays the advantages and disadvantages that an intelligent building has, as well as it traces the link between the advantages/disadvantages and the energy consumption management. The paper was realised by gathering information about household energy uses, renewable energy sources and technology. The research shows how the energy use can be monitored and controlled using the technology of an intelligent building and gives perspective on how renewable energy sources can be used in an intelligent building household.

3. Advantages and disadvantages of intelligent buildings

Intelligent buildings have many advantages (figure 2). The most important one is the comfort (which translates to a satisfaction about the surrounding environment) that they bring to the occupants. The goal to an intelligent building is to create a safe, healthy and comfortable place for its occupants and this goal is achieved when the users can control the building's systems and appliances, even remotely. Smart buildings have an intelligent set up that allows its owners to control the appliances remotely, using an internet connection. In addition to this, the comfort in a smart building can be achieved through a good design.

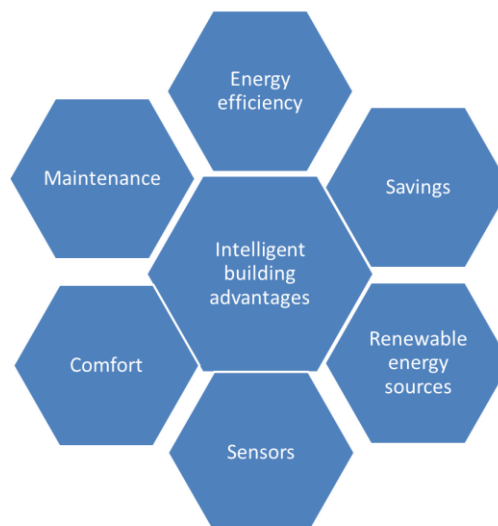


Figure 2. Advantages of the intelligent buildings.

The thermal comfort (the user satisfaction with the thermal environment) can be achieved by maintaining a good thermal environment, regarding the temperature, air quality, heat loss, humidity etc. Besides the thermal comfort, the acoustic comfort is also important, and it is achieved with a good acoustic insulation. The lighting affects the comfort directly and it is taken into consideration when designing an intelligent building. Lighting is also important in the comfort of an intelligent building, since different spaces (designed for different activities) require different lighting levels.

Tab 1. Energy consumption in households [5].

Space heating	63.6%
Water Heating	14.8%
Lighting an appliance	14.1%
Cooking	6.1%
Space cooling	0.4%
Other	1%

In the European Union, the energy consumption in 2018 in households are as shown in table one. The energy consumption in an intelligent building is an important step that is taken into consideration in the designing and construction stages. It is important to meet the occupants comfort level, but also have a building design with an energy consumption rate as small as possible. First of all, there is the thermal insulation that reduces the heat transfer, both during winter and summer, by keeping the temperatures between a suitable range. The building envelope should be designed in such a way that the heat transfer is minimal. The building envelope is the direct link between energy loss and energy consumption. The maximum energy efficiency is achieved as long as the heat transfer is minimal. Second of all, energy efficiency is achieved also when providing a significant reduction of electrical energy consumption. This means controlling the appliances energy consumption and using low energy light bulbs.

In the European Union, in 2015, only 15.7% was covered by renewable energy sources (figure 3). An important advantage of an intelligent building is the use of the renewable energy sources. An intelligent approach to an intelligent building is integrating the energy production by using renewable sources, such as solar, wind and geothermal. The most used technologies that can be integrated in the building's energy system are photovoltaic systems, solar thermal, geothermal heat pump and wind turbines. Usually for the electrical energy production, the photovoltaic systems are the most used [6-8]. The small wind turbines that can be installed near the building are less used, since they take up valuable space and they can make too much noise. For heating the space, the geothermal heat pump is the go-to-choice.

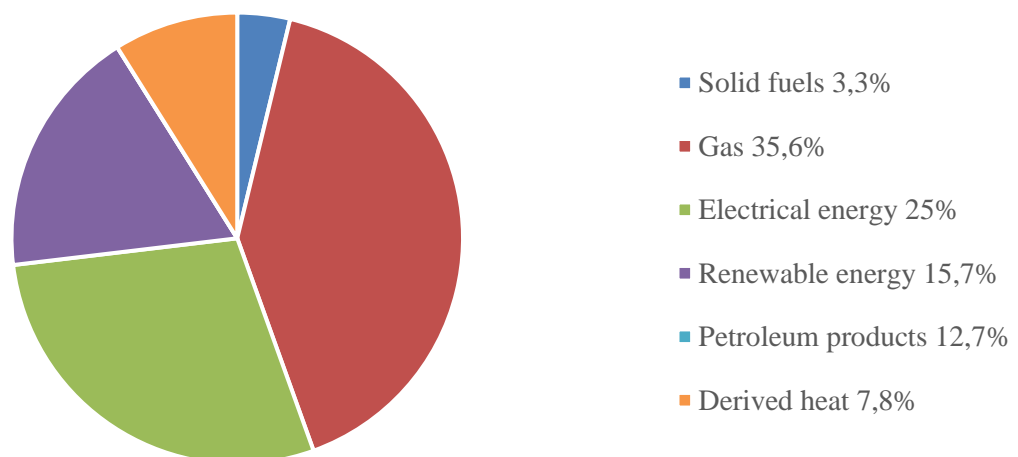


Figure 3. Final energy consumption of households by energy product, EU, 2015 [9].

A great advantage of an intelligent building is the fact that they have a hands-free convenience and that they save time with the automated tasks. For example, the sensor system that the building has can detect many of the malfunctions of the systems, alert the owner and therefore the failure can be fixed in time, with a minimal investment. This system offers a simpler maintenance and less expensive interventions taking into account the fact that the defects are signaled in time.

On the other hand, one of the main disadvantages (figure 4) is the higher investment that an intelligent building requires. Some of the technology mentioned is usually more expensive. Also, a smart building integrates the energy production systems that have a higher price-tag, but over time, the investment pays off. For example, the investment using a heat-pump for space heating instead of a classic methane gas heating system would be higher. However, over the years savings will be made because the user will have the needed energy produced on site, instead of paying for non-fossil fuels consumptions (mains gas). Finally, by designing an intelligent building with an on-site renewable energy sources system, the the necessary energy will be produced and there will be little to no need to pay for electricity or heat(gas).

Another disadvantage is the dependency on the professionals. Usually if there is a malfunction in the smart-system, there are only a handful of people that can take care of it. Compared to conventional buildings, which also need professionals, here it takes skilled people who have the necessary training to solve problems in terms of new technologies that are implemented in the intelligent buildings. Usually, the companies that installed the system provide help and handle the problems. The last disadvantage refers to the fact that an intelligent building needs a reliable internet connection for the remote use and access. Therefore, if technology fails the user could be helpless.



Figure 4. Disadvantages of the intelligent buildings.

4. Conclusions

This paper summarizes general ideas about intelligent buildings, regarding the link between advantages and disadvantages and the energy consumption and management. As a future research direction, the study will continue with the idea of reducing the energy consumption and reducing the carbon footprint, with references to other studies.

The intelligent building systems are the future of the building sector. Investing in an intelligent building can affect the energy consumption of the household, therefore on the long run there will be significant savings. Most of the energy in households is consumed by heating the spaces, so significant savings can be seen by insulating the envelope and by designing the space heating properly. The use of renewable energy sources provides lower running costs, reduce carbon dioxide emissions, which meets with the green and sustainable directives. Switching to renewable energy sources when designing an intelligent building decreases the fossil fuels usage for power generation in the building sector. Also, switching to renewable energy sources will help decrease the energy consumption costs over time for the building. Usually the investment is rather higher, but usually it pays off over time, since the needed energy will be produced on site. Smart homes are set up with wireless or hardwiring sensor systems and they are built in such a way that they have a low energy consumption and rely mostly on renewable energy sources. Also, air pollution in human activities is increased by the use of fossil fuels in households and in the building sector for power generation [10].

An intelligent building has an automation system which is able to provide information about the linked systems by using sensors. An intelligent building offers a higher level of comfort, both for a home or a work space, provides enough information in order to prevent energy losses, it can detect early malfunctions and allows users to access the system remotely.

Optimal energy management and energy efficiency in the building sector is a valuable tool for conserving natural resources. In addition, the financial benefits of using renewable energy are a major

motivation for building owners. As a future research direction, energy efficiency and environmental protection measures must be treated differently in the design phase and in the operation phase.

Given the inherent limitations of traditional design methods, are we still surprised that our energy systems often fail to achieve their performance? Many of the buildings in the world, but especially in Romania, have an annual energy consumption of around 300 kWh/m².year, the energy conversion and transport systems work with a much lower efficiency than their optimum, and the needs of human comfort and health are seldom fully met.

Architects and investors are indirectly involved in the development of energy efficient systems, but can play a very important role in the widespread adoption of these systems or technologies.

To overcome the simple role of thermal/sound insulation system, a building must be controlled by a BMS (Building Management System) which allows, in addition to monitoring comfort and energy parameters, a complex control and efficiency.

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