THE ECONOMIC BENEFITS OF SMART HOMES

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The aim of this article is to study the pros and cons of smart homes equipped with a wireless assembly of devices for home automation. An optimal solution for better energy savings and increasing user's comfort was presented. Starting from the initial construction price of the smart home that was implemented it is shown how the energy consumption can be minimized through the advantages that a smart system brings. The structure offers complete wireless control of the house from any distance - it provides the functions of a finer control of the lights, temperature, shutters and ventilation all within a smartphone control app with internet connection. The energy saving is reached by using LED lights, smart thermostats, controlled blinds and a controlled air conditioning system. For all these the user can create different scenarios of functioning so that they work in the most energy efficient way.

Keywords: smart home, energy consumption, efficiency, control systems, wireless

1. Introduction

Smart homes represent the future of interior system design, transforming through technology the immobile state of the house into a truly interactive home. From the first step, when the first electric vacuum cleaner was invented [1], followed by the construction of the first smart houses [2] and until now the field of smart buildings is in continuous development having one of the biggest growths in the technological sector. A component that plays an important role in the development of intelligent systems is the multidisciplinary of the field.

The area of smart buildings thus reaches different fields, such as: sensors [3], electrical and electronic measurements, electrical installations, programmable logic controllers, electrical automation, electric motors, electrical compatibility and many more [4].

The main characteristics the smart systems bring to the table are [5]:

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- Functionality - fast and remote command of all items controlled by the smart home and the creation of operating scenarios to increase comfort and efficiency

- Energy management - through an optimization of the systems used and by optimizing the operation of energy consuming components one can reduce energy consumption.

- Security system - is a very easy system to implement in a smart home and is an increasingly desirable need in the current time.

Economic efficiency is a topical concept that involves matching costs of investment with benefits that follow for a better financial outcome. To analyze the economic part involved in smart buildings the energy consumption reduction will be observed. Also, the economic efficiency will be analyzed by matching the construction cost with the reduction of the related electricity consumption.

The concept of smart homes is a well discussed topic in today's engineering world. Many studies have reached this subject from which it can be mentioned: energy management algorithm for smart home with renewable energy sources [6], energy consumption management due to: ON/OFF scheduling [7], energy storage and PV rooftop [8], smart thermostats [9], smart meter data [10], internet of things [11], smart home governance [12] ÷ [14], etc. Apart from the topic of energy efficiency smart homes have also been the subject countless types of studies like: systems for elderly households [15], smart routing systems [16], data encryption systems [17], carbon emission saving [18] and many more.

2. Methods used in the implementation of smart homes

Regarding the materials and methods used in the implementation of smart homes, there are currently many systems created by various companies to customize the home to one's liking. These includes:

- Amazon Alexa
- Apple HomeKit
- Google Assistant
- Samsung SmartThing
- Eaton xComfort
- Control4
- etc.

In the case of the smart home implemented and analyzed in this project, the Eaton xComfort - RF Smart Home Solution system was used, which represents a wireless assembly for home automation.

xComfort communicates wirelessly on the 868.3 MHz frequency band, a radio frequency band allocated to home automation systems in Europe. The coverage radius of the system is 30-50 meters in structures that do not contain walls that

can block the signal, but the extension of the radius can be done by using routers. The Eaton xComfort system can be used to control lights, shutters and temperature control, being recommended for a residential area or a small office space [19], [20].

The system that is going to be created will contain:

- 17 switches
- 7 radiator thermostats
- 10 on/off actuators
- 3 room thermostats
- 3 consumption measurement sensors
- 1 Smart Home Controller
- 5 shutter actuators

Regarding the creation of the system itself, the smart home system is initially created in a specialized software. The first step is to create the rooms as logic blocks in the system and then to add the central control unit and the mini room controllers – as shown in Fig. 1.

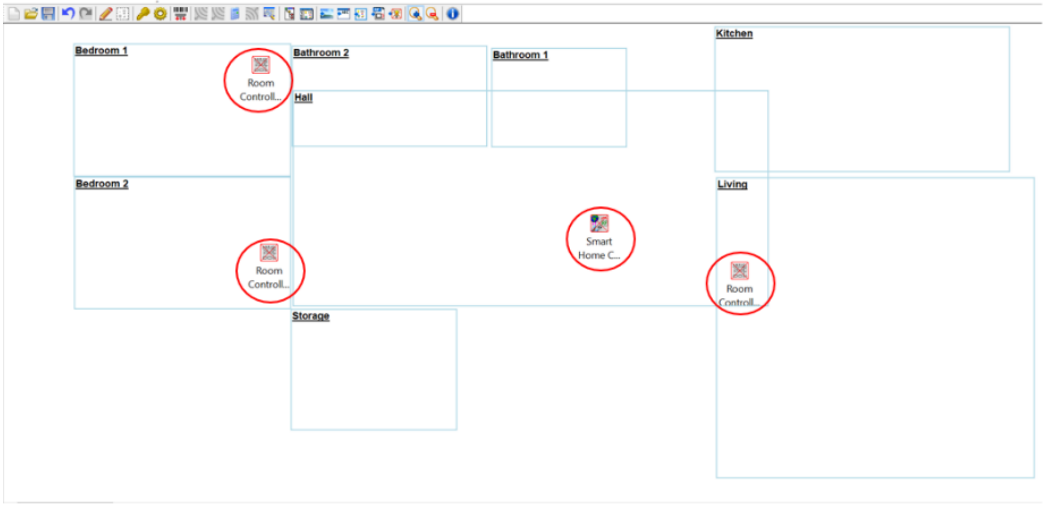

Fig. 1. Creating the rooms and adding the Smart Home Controller and the Room Controllers.

In Fig. 2 the lighting actuators and the ventilation will be added to the smart home structure.

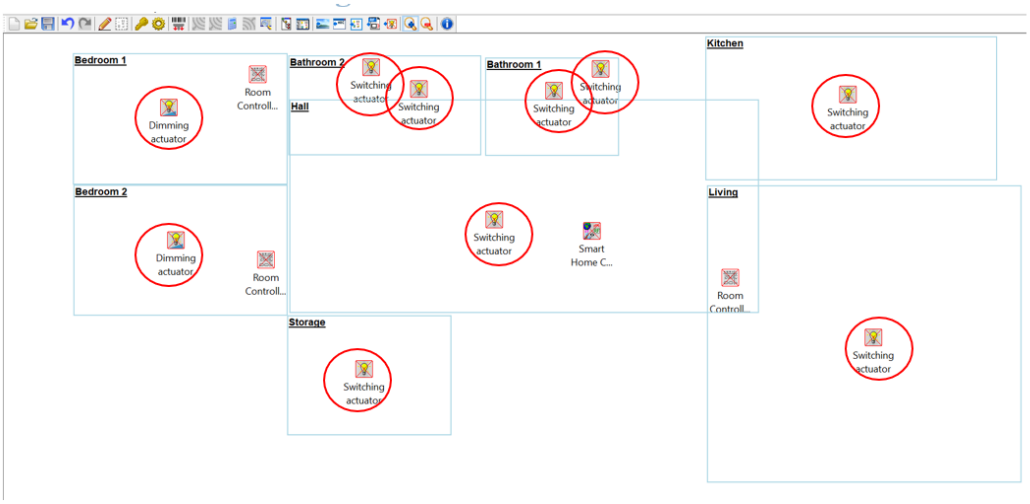

Fig. 2. The addition of the switching actuators to the system.

The next elements added in the system are the solenoid valves for the radiators and the shutter actuators for the windows as shown in Fig. 3. In Fig. 4 are added the energy sensors for a better control of the electrical consumption and the switches for all the actuators that the house is equipped with.

Once the scheme is ready, the owner's approval is obtained, the necessary equipment is installed in the predetermined spaces and the physical equipment is correlated with those in the simulation.

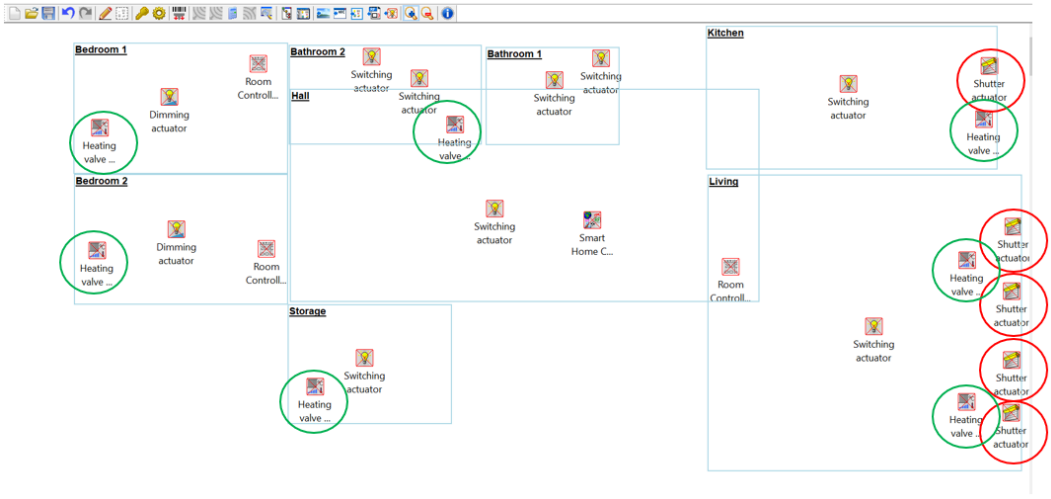

Fig 3. The addition of the shutter actuators (red) and the radiator thermostats (green) to the system

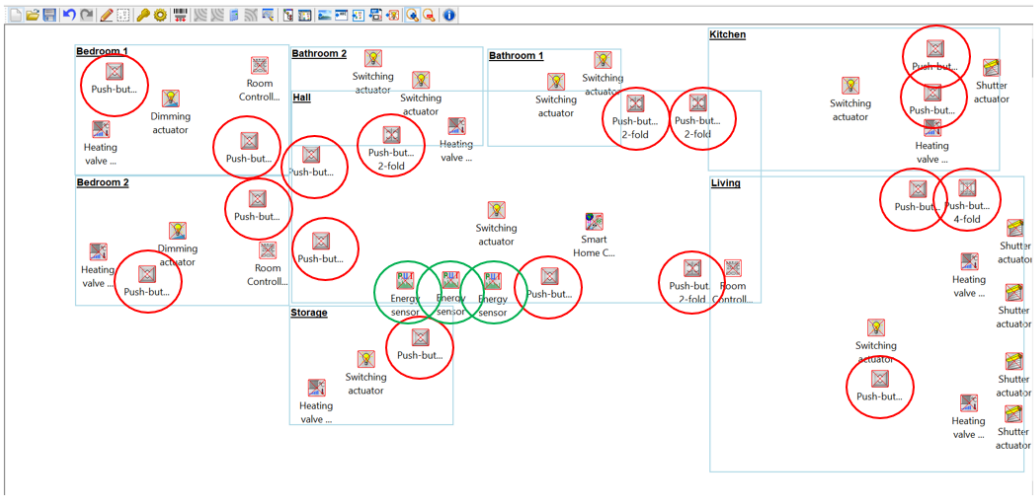

Fig. 4. The addition of the push buttons (red) and the energy sensors (green) to the system

The program that is created is downloaded from the application and uploaded to the central control unit of the system to ensure operation. After this step one can say that the actual physical system works.

Regarding the methods of minimizing energy consumption, this will be achieved by creating operating scenarios through the related mobile application. Through it one can control all the elements of the house from any distance as long as the phone and the central control unit have an internet connection.

3. Results and discussions

One of the main differences between a non-smart house and one equipped with an xComfort system is the absence of wires, the smart home implemented being equipped with a wireless system. Knowing the number of equipments needed for the smart home that was implemented, list that is presented in the previous section, the price of implementing the smart home is 5,300 € from which the labour is 25%. This estimate was analysed extensively in [4]. A plus in the cost of the wireless system are consumables, only ordinary batteries with an average life of 1-2 years for switches and mini-controllers and 3-4 months for radiator thermostats. For a non-wireless house of the same dimensions as the designed house (120 m^2), the cost of materials plus labour is between 3,500 € and 6,100 €. This price includes wiring, sockets, switches and connections required for lighting installations [21].

Considering the functions performed by the implemented smart home are the usual ones, for the price of a normal house we will consider a price of 4,000 €. Even though the cost of implementing a smart home is higher, there are several

advantages: higher number of control units, exact control of parameters, the possibility of creating operating scenarios and remote control.

Another difference between these two constructions is the time in which they are implemented. It can take up to 4 days to implement an intelligent system, while the work required for a normal system can take weeks, time that implies a bigger cost.

In terms of the number of equipments one advantage is that the smart home has several ways to control the lighting system. While a normally implemented home has on average only one switch per room, the wireless solution offers multiple switches without the need to mount wires through the walls of the rooms. Analysing the general requirements of customers one can observe that it is preferable to install two switches in each main room (living room, bedroom), one located on the wall at the entrance in the room and a mobile one that is usually placed in the most used point of the room. This type of intelligent wireless system has the advantage of not having to invest time and money in wiring the equipment.

Another advantage in terms of the number of equipment is the very easy addition of new equipment to the system. For example, while a typical house requires a special system and related wiring for the remote control of an air conditioner, for a wireless smart home a small equipment that costs about 20 €, less than 0.5 % of the total price, can be mounted on the air conditioner and once entered added to the smart system its control will be possible from the mobile application. Among the equipments that can be added are: door and window sensors, motion sensors, gas sensors, air quality sensors, smoke sensor, water drain sensor, car charging station built into the wall or on the support, etc.

The most important parameter that brings a plus to the energy saving of the smart home is the temperature control. It is maintained by multiple factors including: control of radiator solenoid thermostats, air conditioning control, door and window sensors and control of shutters through the mobile application.

Compared to a classically implemented house with a wire system, the intelligent wireless system offers a much finer control of the system characteristics. At any time of the day, the temperature measured by the radiator thermostats and the mini room controllers is displayed in real time on the mobile application related to the system.

Analysing the function of radiator thermostats here are multiple modes of operation that set a certain temperature until which the radiator will consume energy and heat the room, and after reaching that temperature the heating system will stop and stop consuming. This is a major plus in economic consumption compared to an ordinary house where radiators if not turned off they continue to consume. The setting modes of the radiators are as follows: Frost Protection (5 °C), Comfort (24 °C), Economy (22 °C), Standby (15 °C) or User that can be

set to any temperature the user wants. To bring the consumption generated by the radiators to an economic minimum and to a maximize comfort, the Eaton xComfort system proposes the possibility of creating an operating scenario for each radiator in the house. Thus, one can set the temperature at night to 24 °C, between 6:00 and 9:00 at 26 °C, from 9:00 to 17:00 can be set to 22 °C and from 17:00 to 24:00 to 26 °C. These scenarios are saved until the application is stopped, operating without the physical start of each situation.

Another functional option involves coupling the logic of the radiator thermostat with a door or window sensor. This sensor is activated when the door or window on which it is mounted is open and it will turn off the radiators to reduce inefficient heating. Once the window or door is closed, the selected thermostat program will restart by heating the house. This mounting possibility serves a major advantage, improving both the ventilation and heating function of the house.

After the implementation of ways to increase the economic efficiency for temperature control on the heating side, the cooling side follows. The system that deals with the cooling function of the temperature consists of the air conditioners in the house. They can be added to the Eaton xComfort smart system with the help of a mini actuator and will work on the same principle as the radiator thermostat. The application will select the temperature to be reached, the air conditioning will start and it will stop when the room temperature reaches the set temperature. This function decreases the operating time of the air conditioner and maintains a relatively constant temperature in the home without requiring a higher cooling power.

The use of an intelligent temperature control system can reduce heating and cooling consumption by up to 15%, which is a high percentage considering that 40-60% of annual bills consist of this function [22].

A very serious problem during the summer season that causes the temperature to rise is solar radiation. The building model considered has a wall in direct contact with the outside made almost entirely out of windows that lead to a huge increase in temperature. This wall is oriented to the South, the cardinal point where the sun's rays have the greatest power, bringing an increase of up to 10 °C in the house.

To minimize this problem, the architect of the housing complex equipped each wall of windows with electrically operated shutters. The plus that the smart home brings to this problem is the remote control of the shutters and the possibility of creating operating scenarios. For real-time remote control they can be closed or opened with the help of the mobile application from any distance, this detail minimizing the risk of overheating the house.

The second and most rigorous setting option involves creating a scenario that will close the shutters in the summer months between 13:00 and 19:00, the

hours with direct sunlight. Considering these protection measures against heating due to the sun's rays, it will result in a more controlled room temperature, therefore, a lower consumption of electrical energy by air conditioning.

In Fig. 5 is presented a diagram of the reduction of energy consumption achieved by mounting radiator thermostats and using air conditioning and shutter control.

In the winter season, the presence of shutters can reduce heat loss through windows by up to 40%, thus consuming up to 10% less energy for heating. During the summer they can reduce the heat due to the sun by up to 80% [23].

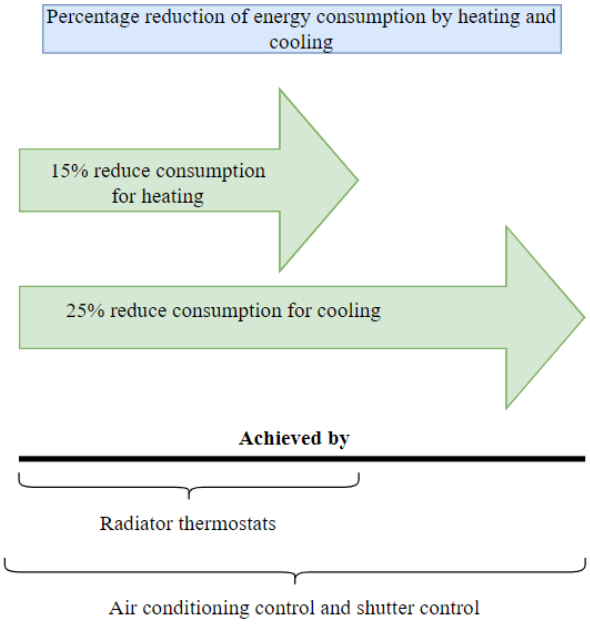

Fig. 5. Percentage reduction of energy consumption by heating and cooling.

Analysing the ON time of the lighting fixtures the intelligent system proposes a much more economical control. The lighting system is displayed room by room on the mobile application as ON or OFF, so you can see from a distance if a light has been forgotten turned on and can be turned off.

Regarding the general consumption of the lighting system, this is a relatively small one because the whole house was equipped with LED type fixtures. Even if LED bulbs are more expensive than incandescent bulbs, they end up consuming up to 75% less electricity – Fig. 6. A 100W incandescent bulb consumes approximately 876 kWh annually if it were lit continuously. An LED bulb that has the same light output has a power of 16W and consumes 140 kWh annually [24], [25].

Analysing smart lighting solutions it results that even if it is more expensive than traditional lighting it presents a series of advantages from which we can mention some. Traditional lightbulbs are not energy efficient because only 5% of electricity is converted to light and the rest of 95% is converted to heat. The smart LED lights are cost efficient for this matter as they do not produce heat. Another advantage that smart homes can bring in lighting is the substitution from normal switches to dimmer switches. Dimmer switches can adjust the amount of voltage moving through the switch circuit in this way adjusting the energy consumption to the need of the user for better energy usage. By pairing the lighting fixture with a motion sensor in every room energy can be saved by turning the lights of if the sensor does not detect any movement.

Regarding the ventilation system it is programmed to shut down 3 minutes after starting for not unnecessary consumption of energy. Another mounting method that the smart home allows very easily is the installation of a smoke detector near the ventilation system which, once turned on, will close the ventilation system when the air has optimal parameters.

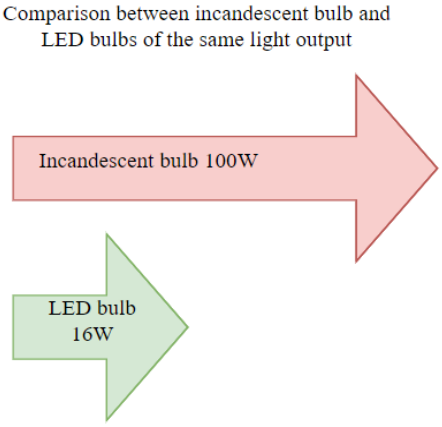

Fig. 6. Comparison between incandescent bulb and LED bulbs of the same light output.

Apart from the economic benefits, one more advantage that smart homes bring is the increase in user's comfort. This is achieved by three motives: firstly, the automation is fully wireless so that implementing the system and resolving possible problems is much easier and does not provide discomfort for the user. Secondly, every modern smart home system is equipped with a mobile app which allows the user to control the house's function from anywhere as long as it has internet access. For example, you can turn on the heat an hour before the user gets home so that the temperature is reached by the time he gets home. The third plus in comfort is the possibility of setting different scenarios to be activated at every hour that they are set to be. For example, you can set to close the blinds by noon

and open them after 07:00 PM or plan a schedule for heating where you turn them on one hour before waking up and one hour before arriving home. Plus, by adding different sensor the comfort can be boosted – e.g., by adding a photoresistor we can close the blinds if the outside light is too bright or by adding an open door sensor we can close the radiator electro-valve when the balcony door is open.

4. Conclusions

Smart wireless home control systems are the future of construction and interior design. Even if such a system is more expensive than a normal system, it can produce multiple savings through its specific functions.

In terms of construction, one can save time and effort through the ease of installation of the system that does not require wiring through the walls. Taking into account this fact, multiple equipments can be added in the system without making constructive changes in the house structure.

Analyzing the consumption of the smart home it can be concluded that: the use of smart LED bulbs can reduce by up to 75% the cost of lighting, the use of smart radiator thermostats can reduce the cost of heating by up to 15% and creating a shutter operating scenario can reduce by up to 25% consumption generated by the cooling system.

Following our analysis, the price for implementing the smart house is up to 33% more expensive than the normal house with the same functions, but this price is recoverable over time. In conclusion, based on our assumptions, considering all the details listed above, the house built with a smart system will reach economic efficiency in 6-7 years, during which time the comfort will be much higher.

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