Smart Houses: Domotics Application to Reduce Energy Waste

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Abstract— **The inefficient use of electrical energy at home produces not only big waste of energy, but also an increase in general costs like maintenance of devices and the energy bill. Many people are not aware of how important and economical it could be to make the use of services in an efficient way. In this paper, an innovative solution is presented in order to reduce energy waste at home. The system used is called "domotics" and controls the different parts of a house providing energy management, security, well-being, and communication services.**

Keywords **– domotics, home automation, energy savings**

Resumen— **El uso ineficiente de la energía eléctrica en los hogares, no sólo produce un enorme desperdicio de energía eléctrica, sino que también un incremento en los costos de mantenimiento de los dispositivos y en la factura eléctrica. Mucha gente no es consciente de cuán importante y económico podría ser hacer uso eficiente de los servicios. En este trabajo, una solución innovadora es presentada con el fin de reducir el desperdicio energético en los hogares. El sistema se llama "domótica" y controla diferentes partes del hogar proporcionando manejo de energía, seguridad, bienestar y servicios de comunicación.**

Palabras clave **– domótica, automatización de hogares, ahorro energético**

I. Introduction

Waste of energy is a common issue in everyday life and many people do not even realize it. If each house is analysed individually, the problem does not seem to be so serious, but if the focus is on a neighbourhood or an entire city, spending increases considerably.

Energy production also generates pollution, such as greenhouse gases. This means that if energy is not used efficiently, a greater production of energy to supply consumption will be needed. Therefore, more environmental pollution will be generated. This directly affects the people who live near the centres of energy production.

Frequently, people are not aware of the benefits of an improved home through simple things such as good ventilation, better illumination, and temperature regulation. This energy need could be the opportunity to improve the use of electrical energy, achieving a reduction in unnecessary spending and the opportunity to improve lifestyle.

Domotics is the integration of technology in housing design that can improve the above-mentioned aspects. The development of domotic houses has increased in the last few years in order to improve people's life quality. An automated house is a house with devices, appliances and sensors communicating with each other and with the possibility of being controlled remotely. These functions allow consumers to monitor their electricity consumption and decide about safety and comfort.

This technology helps maintain a healthy environment through the intelligent use of electrical energy. These are the two most important benefits of home automation.

The purpose of this paper is to delve into and analyse the results of different studies about home automation and how it affects the environment and the user's quality of life. To achieve this aim, this paper is organized as follows: section II, Previous Research, describes the construction of a home automation system, its energy consumption, and the effect of this product on the environment. In section III the impact of this system on a user's life, its advantages, and disadvantages are introduced.

The United Nations' global agenda proposes 17 objectives aimed at solving problems of both humanity and the environment through the development and innovation of new technologies. This paper also seeks to inform about how home automation can help achieve the targets connected with the Sustainable Development Goals (SDG) in relation to SDG#3: Good Health and Well-being, SDG#11: Sustainable Cities and Communities, and SDG#13: Climate Action [1].

II. Home Automation Systems' Basic Components and Operation

Many parts of an automated home works simultaneously to keep it running smoothly. These parts must be managed through different systems in order to keep consumption stable and avoid increasing the carbon footprint.

A. *Parts of a Home Automation System*

To have an automated house it is necessary to have different interconnected subsystems: temperature controls, lighting controls, security systems (related to gas control, fire, surveillance, power, etc.), audio-video subsystem, gates' control and data communication security [2, 3]. Mainly, in [2] the Home Energy Management System (HEMS) is presented. This system is most usually classified into the following subsystems: smart meter, communication devices, field devices and management devices.

The smart meter is responsible for collecting the information of the house through the smart plugs. Each device can have its smart plug to transmit the information to the smart meter, but it is not of vital importance since the total energy consumed is saved in the same way. This is used, for example, if an appliance in the house is consuming too much energy. The system would detect which appliance it is, and something would be done about it. Otherwise, without the smart plugs this would not be possible since the electrical consumption would not be differentiated by devices, and just the total consumption would be seen.

The communication device is necessary to transmit the data between the plugs or devices and the users or to the centralized aggregator. This is achieved with devices that can use the internet or some technology to transmit information.

The field devices group all the electronic equipment and/or the communication equipment that allow recording and controlling the appliances. These devices are connected to the smart meter and to the management devices. These field devices also include technology such as an external temperature sensor.

Finally, the management devices are composed of the hard disk to save the collected information, the in-home display and the computing power to process the data. There are two main ways to retrieve the information about the energy consumption of the house: web based and within a home display. When the system used is web-based, the existence of a computer with an internet connection is needed to collect and upload the data to the network. If a system with a screen system is used inside the house, the data collected on the energy consumed is much more directly obtained to inform the user.

In addition to the HEMS system, [4] describes a system called Semantic Smart Home System for Energy Efficiency (SESAME). This system contains the same subsystems as HEMS', but with the difference that it allows the different appliances to be turned on or off. The system can also detect temperature and humidity signals using the sensors to choose a necessary setting. For example, if a sensor detects high temperature inside the house, it could turn on the air conditioner or some other similar system to regulate the temperature.

From the systems shown, it can be seen that automated houses are divided into two main categories, those with microcontrollers and those without. The former can regulate the appliances automatically and the latter are limited to displaying the information collected in order for the consumer to make the changes.

B. *Energy Consumption*

In [3], an experimental low-cost setup based on STM32F407 microcontroller was carried out in a four-season geographical area in order to generalize the results to any part of the world and know how this system can behave in every type of environment. This simulation of home automation had a microcontroller which is connected to a temperature sensor, a light dependent resistor, a smoke sensor, solid state relay and auxiliary materials, and an electric underfloor heating system mounted to the building.

Above mentioned elements are used by the microcontroller in a smart way to reduce inefficient energy costs. For example, if the light sensor notices that it is getting dark, the microcontroller will gradually increase the lights of the house in the rooms that are being used. In this way, energy is saved since not all the available power is used, only the necessary amount. A similar phenomenon takes place with the rest of the sensors. When these detect that energy is being used and is not needed, the microcontroller regulates them (i.e. sensors). Thus, small energy savings are achieved that accumulate over time, resulting in important changes in the overall consumption of the house.

After monitoring energy consumption in the first eight months, it was found that there was a further reduction in consumption by approximately 15%, reducing from 1159 KWh to 787 KWh in the eighth month of use and having an average consumption in these 8 months of use of 1053.4 KWh per month. In this case, the usefulness of the lighting subsystem was demonstrated. The light will automatically turn off in those areas where no movement is detected in time intervals of 5 minutes. It is important to know that the consumption is going to depend on the kind of system that is under study.

Similarly to the previous case, in [2] it is assumed that home automation can achieve a reduction in electricity consumption of 12% in the appliances. In this study, the consumption of each of the HEMS' categories is analysed and multiplied by an average operating life of 5 years. However, in order to achieve a comparison with the previous case, a monthly average is sought. Taking this into account, the results are as follows: the total consumption of the automation system in 5 years is 4558.32 kWh, which means that the monthly consumption is 76 kWh [2]. The difference is that in this study, unlike the previous one, only the house system is studied, not the appliances that are part of it.

With the data provided in this section, it is possible to know not only the percentage reduction in electrical consumption but also the consumption of the isolated system. In this way, in the next section, its environmental impact compared to the benefit that it offers can be established.

C. *Carbon Footprint Calculation*

To have a future with cleaner and more sustainable cities and communities, the carbon footprint must be considered. The method used to study the carbon footprint of the home automation system not only requires analysing the energy consumption but also its entire life cycle. Life Cycle Assessment (LCA) is the method used to measure the effect of the system on the environment. this method is based on analysing the effect of a product on the environment in a life cycle.

The life cycle begins with obtaining the materials from nature, followed by their processing and transportation. After these initial steps, the cycle moves to the manufacture,

shipping, use, reuse, possible repairs, recycling and finally ends when the product is discarded.

In [2] the LCA of an average automated home was performed in relation to devices classified in communication, field, computing, management, and the smart meter described above. The LCA results show that 99.4% of emissions occur during the assembly and use phase and this last phase of use makes up 84% of the previous percentage. Then, the study is divided into 18 indicators, as shown in [Fig. 1, [2]], which reflect the environmental impact of the system on different areas. In this paper, only the most important ones are highlighted since the point is to identify which components that most affect the environment are as opposed to identifying which part of the environment they affect.

The most affected index is marine toxicity, by which management devices occupy 40%, the smart meter occupies 21% and smart plugs 39%. The second largest index is human toxicity, by which the main devices that affect it are those of management. Freshwater eutrophication and freshwater ecotoxicity are the following indices with a considerable impact but very far from the first two.

In general, the temperature sensor has an almost zero impact, the smart meter has an impact close to 20% within each of the indexes and the management devices smart plugs share the highest percentages of all categories. If the study focuses on climate change and how harmful HEMS is for it, it is estimated that smart plugs have the greatest impact due to the number of devices and the continuous use of electricity. When electricity is not considered, the value of 354 kgCO2 is reached, unlike the electrical consumption during a period of use of 5 years, where the value of 2076 kgCO2 is reached. This means that the electrical consumption of the HEMS is equivalent to 1722 kgCO2 emitted.

Taking all the information above into account and reviewing the electricity consumption data, it can be said that environmental investments according to [2] are not amortized. However, in terms of energy consumption the smart meter can be paid back in 3.5 months, which means that the remaining months are beneficial in terms of electricity consumption. In terms of CO2 return, the smart meter would pay itself after 11 months. Even so, a point against this study is the relationship between gas emitted according to the LCA and energy consumed.

The average value of gCO2 per kWh consumed according to the International Energy Agency (IEA) is 199 gCO2 / kWh while this system reaches the value of 455.43 gCO2 / kWh. These results can be improved if materials with lower CO2 emissions are used in their manufacture or that can be recycled. In addition, it must also be considered that the consumption of household appliances is reduced when automated systems are used.

III. USING HOME AUTOMATION

When it comes to designing a secure and stable system, the most important aspect is to test the system in operation. This provides information about areas for improvement.

A. *Improved Well-Being*

One important aspect of home automation and probably the main reason why people use it is the security provided. Many systems have been developed that cover efficiently every possible security need. A security and safety system aimed at smart homes must support several different purposes. Such systems detect the outbreak of fire at a very early stage by means of a temperature sensor, inform about possible flooding and some limit the human access to indoor and outdoor places [4].

Safety is provided in home automation with sensors, such as smoke detectors (used both in household and industrial applications because it can also detect marsh gas, propane, butane, GPL, alcohol and hydrogen) like the MQ-2, gas detectors such as the FCM6812 (this provides a quick gas detection, being precisely calibrated during the manufacturing process) and magnetic sensors (to detect unauthorized opening of doors or windows). Added to this, the access to the setting menu of home automation takes place

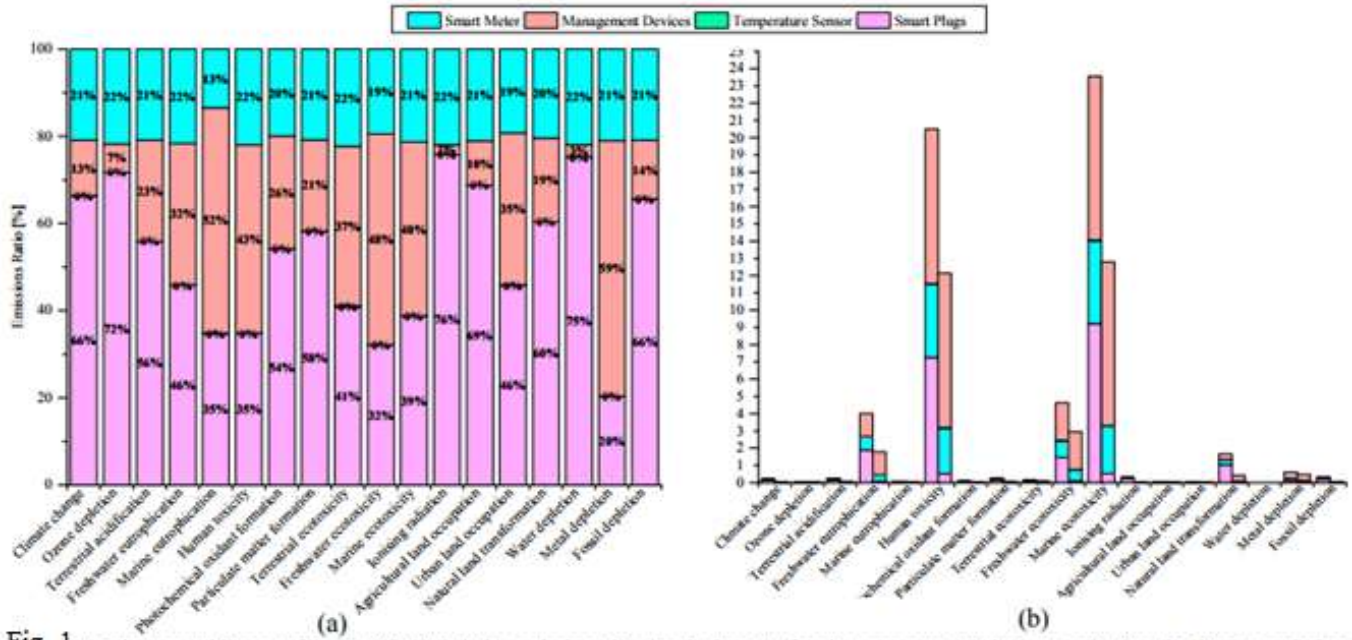

Fig. 1 Environmental Impact of the HEMS. (a) Relative emissions showing the impact of each components relatively to each other, (b) absolute emissions illustrating the relevant impact when considering the use-phase (left bar), and without the use phase (right bar).

in a secured way in order to avoid the access of unauthorized persons to the entire home automation system using fingerprint scanner [3].

B. *Community cases with home automation*

This paper has delved cases of home automation that have been used in different parts of the world as are analysed in [2], which is located in Finland, and [3] which is in eastern Europe. In addition to this, cases presented in [4] will be analysed below. This purpose is in order to analyse how home automation adapts to a city or how home automation can help if it is used on a large scale.

The first case to be analysed is the case of the city of Chongqing in China. In this city, a survey was carried out on the attitude of 246 consumers towards saving energy over the course of a year, between 2009 and 2010. This survey was done because China's energy consumption doubled from 2000 to 2008 as a consequence of the increase in electrical appliances within the homes of that country.

To try to solve this problem, the government launched measures such as improving power plants, labelling devices according to their energy efficiency and promoting the purchase of these, together with the prohibition of inefficient equipment. These policies were accompanied by the education of the population in relation to energy consumption. Faced with these problems and policies, the survey had different results.

According to the results obtained, the population was aware that energy consumption is a challenge and was willing to make changes in this regard. They were informed about the price of energy but there was a lack of knowledge about how to save energy at home, how much each appliance consumes and what habits they should change. Is the point where home automation could be applied.

Using automation, it would be possible to better know how much each device consumes and thus know if it should be changed or if any modifications should be made. Also, in more advanced cases, microcontrollers could be used as in [3] to reduce electricity consumption by means of sensors that reduce or directly cut the electrical consumption of an appliance that is not being used at the time. Thus, the problem of China could be addressed.

The second case to present is a study on the use of Smart Meters on a large scale integrated in houses in a city called Västerås in Sweden. In this place, a survey was carried out on the information that is given to consumers on how to reduce electricity consumption, prices and other important information in this regard. This is because over the years the devices have become more energy efficient, but the trend shows that these elements that consume electricity are increasingly purchased, resulting in higher consumption, despite the improvement in efficiency.

In recent years, millions of smart meters have been installed in homes around the world due to their great practicality to collect data on electricity consumption and summarize it on a screen inside the house, on a website or in a mobile app. This gives consumers a cursory view of their consumption patterns to know what habits should change and which appliances should be replaced.

Contrary to what was expected, the use of smart meters in the city did not help to significantly reduce electricity consumption. The survey revealed that this was due to the fact that these devices do not show enough information about household consumption and consumers are not in a position to make changes with the information provided by their smart meters.

Accordingly, it is possible to see that Smart Meters are important devices to reduce the consumption of a house, but the information it gives and how it is given to the consumer must be reviewed. Surveys like the one in this case can be a very important tool to have feedback that helps improve the development of home automation on the right track.

The next case is again in China, this time in Shanghai, one of the most densely populated cities in the entire country. The study is based on the belief that one of the largest contributors to high carbon emissions is the building sector in China and there is a great demand for a decrease in energy consumption of these buildings.

Since homes are part of buildings, the study explored the energy consumption behaviours of homes through in-home display and smart meters. These devices were installed in two newly constructed apartment buildings. A total of 131 households participated in this study (76 without in-home display devices and 55 with the devices).

Other devices were also installed that helped to collect data for smart meters and in-home displays. The data are transferred from the smart meter where it was shown on the in-home display and then transmitted to the back-end system via the internet. Raw energy data, statistical data and background information were stored in dedicated databases so that researchers could work on the data separately.

The results of the study were classified into the frequency of verification of the in-home display, the saving of electrical energy, the saving of standby energy and the energy consumption in peak hours. The results showed that households without an in-home display consume 9.1% more than those that did have this device. Also, following this trend, houses with in-home displays had a 12.9% reduction in standby consumption.

In the last few years, homes that had in-home displays, the energy was distributed smoothly during the 24 hours. On the other hand, the energy demand of houses without an in-home display was much higher between 7 pm and 11 pm. Therefore, it becomes clear that home automation has a surprising potential to reduce electricity consumption, but this has to be used correctly or it may have the opposite effect. [4]

C. *Advantages and Disadvantages*

Throughout this paper the different functions of home automation that provide consumers the flexibility of monitoring its electricity consumption and making lifestyle changes to save electricity have been developed. However, Smart Home Automation (SHA) not only provides benefits of efficient energy management but also provides benefits such as improved lifestyle, security, and safety, some of these mentioned before. Studies carried out in countries such as Singapore, where there exist programs to control energy consumption, showed a reduction of energy consumption by 20% after implementing Home Energy Management.

On the other hand, studies carried out in different parts of the world showed some negative reactions because people found it difficult to change their lifestyles in order to save

money, although some others found the idea of reducing energy consumption and cutting energy costs highly positive. Therefore, people in different countries might perceive energy saving benefits differently. In addition, another study in [4] has highlighted that households could be categorized as monitor enthusiasts, aspiring energy savers, and energy non-engaged.

The primary reason for people to adopt home automation was about being an eco-friendly household to save the environment. According to the study [4], money saving was the main motivation for the monitor enthusiasts. In terms of costs, many systems offer a part of these facilities at lower price generally, but this is very relative, depending on the country and the purchasing power of the consumer. In addition to this, in [2] the simulations showed that in some cases the environmental investment in terms of home automation does not pay itself back but in terms of CO2 payback, home automation pays itself back after the 11th month.

IV. Conclusion

It should be noted that it is possible to make a striking difference in terms of the electrical consumption of a house if domotics is used. However, for this to be noticed, it is important to distinguish that, as seen in the cases section, the information provided in smart meters is vital for consumers to change their habits. In addition, it is also important that more ecological materials are used to create the electronic components that make up the smart house and that clean energy is used in the house. This is due to the fact that the emission of gases by consumed energy is one of the weakest points in the HEMS system if it is to be used to reduce pollution. In other words, the consumption of household appliances can be reduced surprisingly, but the consumption of the isolated automation system must be improved.

V. References

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