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Chapter 10

Promoting energy efficiency in an eco-school environment

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Abstract

In the past decades, the concept of sustainable development (SD) came into focus and has increasingly gained attention at all levels. Environmental education programs are seen as instrumental in promoting SD, since the preservation of the environment depends on ecological awareness, which depends on education. Higher Education Institutions (HEIs) play a central role in education for sustainable development (ESD) since they provide the knowledge and skills for students to implement sustainable solutions. Polytechnic Institute of Viana do Castelo (IPVC) is a Portuguese HEI eco-school, which promotes, among its community, the search for ideas for sustainable practices. This study aims to demonstrate the importance and effectiveness of ESD at IPVC, through the presentation of two projects developed by students, which intend to improve the energy efficiency in the institution. In the first project, a piezoelectric energy collection system was developed, taking advantage of the movement of people to produce energy. In the second project, a remotely controlled low-cost device was developed, to monitor and control the electrical networks of the school buildings. Despite the need for advanced engineering to optimize performance, first experiments showed very satisfactory results. Both projects are imbued with the spirit of SD and confirm the central role of HEIs in ESD and its practical effectiveness at IPVC.

Keywords: Education for sustainable development, Eco-Schools, energy efficiency

1. Introduction

Since the publication of the Brundtland Report *Our Common Future,* in 1987, the concept of sustainable development (SD) came into focus and has increasingly gained attention at international, national, local, public, and private levels. It became clear that the present consumption and production patterns of developed countries, also aspired by those in developing countries, is recognised as unsustainable (Martins *et al*., 2006). Civilisation is facing difficulties in ensuring sufficient resources for all population to enjoy a life within the contemporary lifestyles, which requires an urgent change in behaviours and life patterns (López-Alcarria *et al*., 2021). It is recognized that ESD can help change the attitudes and behaviour of people in their role as consumers, producers, and citizens to carry out their collective responsibilities and duties (Martins et al, 2006). Therefore, environmental education programmes might be seen as instrumental in promoting the deliberation aspects of sustainability, since they help students to develop knowledge, attitudes, and skills that are important for responsible environmental behaviour (Cincera & Krajhanzl, 2013). HEIs play a central role in the development of knowledge (Martins *et al*., 2006). Therefore, they have a critical responsibility in ESD since they provide the knowledge and skills for students to start to create sustainable development (SD) initiatives. (Caeiro *et al*., 2020). Moreover, HEIs can help achieving the international 2030 SD agenda, ensuring that by 2030 all learners acquire the knowledge and skills needed to promote SD. Therefore, HEIs should integrate SD concepts into their day-to-day practices (Elmassah *et al*., 2021).

Eco-schools is a global ESD programme, developed in 1992 as a response to the United Nations Conference on Environment and Development, where environmental concerns are addressed in the school curriculum and are also reflected in everyday learning practices. In 2003, the United Nations Environment Programme (UNEP) identified eco-schools as a model initiative for ESD, recognising the impact of its methodology on building sustainable communities. It has brought environmental problems closer to students and has encouraged them to identify them themselves (Andreou, 2020). Students increase environmental awareness by being involved in class, school, and community-based events. Students, working together with their teachers, participate in the process of improving environmental school management (Cincera & Krajhanzl, 2013). European Blue Flag Association (ABAE) is responsible for Eco School Program implementation in Portugal and aims to recognize the work carried out by the schools for the benefit of the environment. IPVC is a Portuguese HEI which has implemented the program in its six schools, aiming at applying concepts and ideas of education and environmental management to the daily life of the institution. The concrete actions developed by the students and by the entire educational community make themselves aware that simple individual attitudes can improve the global environment. Students are challenged to participate in decision-making processes, being active and becoming aware of the importance of the environment in their daily personal, family, and community life.

In this context, this work aims to demonstrate the importance of ESD and its effectiveness at IPVC practices, through the presentation of two projects developed by students within the scope of the eco-school programme, in a classroom setting and with the support of teachers. The first (Project A) related with energy generation and the second (Project B) related with the efficient use of energy. Project A intends to produce energy by taking advantage of the movements of people who attend the Higher School of Technology and Management of the Polytechnic Institute of Viana do Castelo (ESTG-IPVC). These displacements cause a vertical pressure on the surface, resulting from its weight and speed. After being pressed, the energy generator transforms this pressure into energy, which is in turn (after being duly rectified), transmitted to batteries. This technology allows the supply of stored energy for the school's emergency lighting. Project B aims to create a simple, low-cost device that allows remote monitoring of an electrical lighting network, promoting energy efficiency. The implementation of a device that can automatically control the lighting of all the building's installations will allow financial and energy savings, not only by reducing consumption, but also by increasing the useful time of the resources used.

Both projects are imbued with the spirit of environmental responsibility widely promoted by the Eco-Schools program and confirm the importance of the role of HEIs in education for sustainable development. Thus, this work should be particularly inspiring to scholar community that intend to motivate, promote, and implement SD actions through the evolvement of students in the development of these sustainable solutions.

This book chapter is structured as follows: chapters 2 and 3 present, respectively, projects A and B, a proposal for its implementation at ESTG-IPVC, and a discussion of results. The main conclusions are outlined in chapter 4.

2. Project A: energy generation

As already mentioned, Project A aims to develop a system for collecting and producing energy through the appropriation of the movements of the population that attends ESTG-IPVC. The chapter begins with a brief literature review that clarifies the basic theoretical concepts related to piezoelectric phenomena, namely the piezoelectric effect and its operation, followed by the calculations and procedures related with the association of piezoelectric components. The final configuration proposal and its implementation is then explained, and results are discussed.

2.1. Piezoelectric concepts

Piezoelectricity is a property that only a few groups of materials have, which was discovered by the brothers Jacques and Pierre Curie in 1880 during a systematic study on the effect that pressure had on the generation of electrical charges by crystals such as quartz. Thus, piezoelectricity is said to consist in the generation of electricity resulting from mechanical pressure. It is also defined as the electrical polarization produced by mechanical stress in crystals of certain classes, and the polarization is proportional to the stress and changes sign with it (Haertling, 1999). Piezoelectric materials are those materials that contract and expand according to the electrical polarization developed by tension efforts. As shown in Figure 10.1, if a piezoelectric disc polarized in the direction indicated by P carries electrodes on both faces, then upon receiving a compression effort it will generate a current external to the circuit. If the effort is traction, the current is directed in the opposite direction (Figure 10.1a). In Figure 10.1b, an electric field is applied to the crystal, which produces a negative strain; if the field is opposite, the strain is positive; The dashed lines indicate the original dimensions (Moulson and Herbert, 2003).

2.2. Piezoelectric system proposal and prototype

In a set of piezoelectric, one of the variables that has a great influence on the system is the number of connected piezoelectric components, since it increases the contact surface of the converter material. Another variable with great influence on the system is the type of association made between them, which results in an increase in the generation capacity of voltage (when associated in series) and electric current (when associated in parallel). To analyse the influence of these characteristics on the response obtained from the system, five connection configurations were proposed, as showed in Figure 10.2.

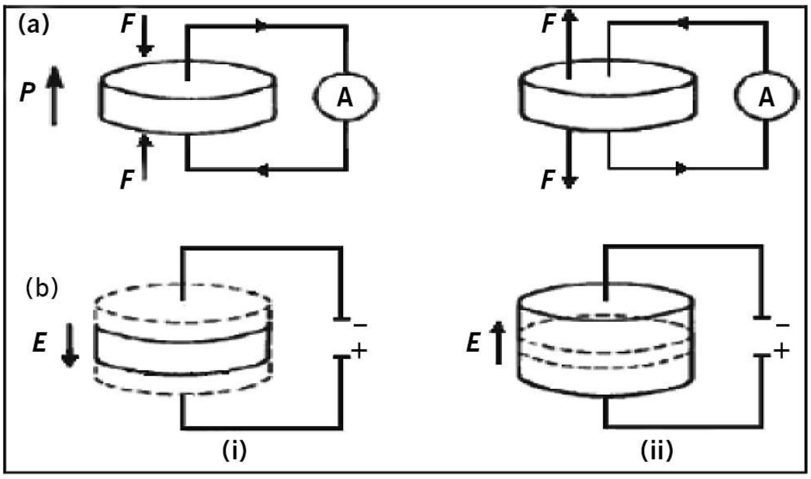

Figure 10.1. (a) the direct piezoelectric effect and (b) the indirect effect: (i) contraction; (ii) expansion. The dashed lines indicate the original dimensions
Source: Moulson and Herbert (2003).

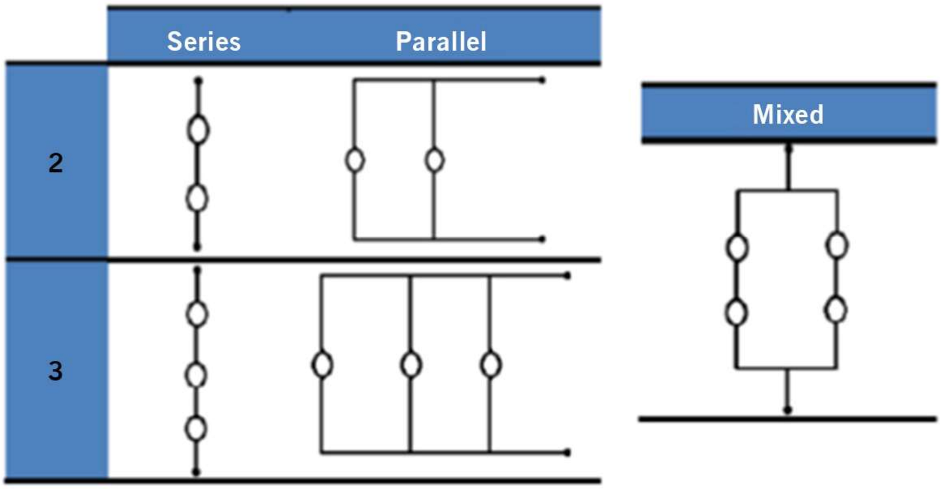

Figure 10.2. Connection configurations with 2 and 3 piezoelectric components
Source: own elaboration.

Using the knowledge of works previously developed at ESTG (Leiras *et al.*, 2014) and consulting other developments of similar structures, it was verified that there is a topology, more or less optimized of the construction of this plate. Considering these experimental issues made with low voltage, it was decided to connect 12 piezoelectric chips, 2 in series connected in parallel with another 2 in series, 6 times, as shown in Figure 10.3.

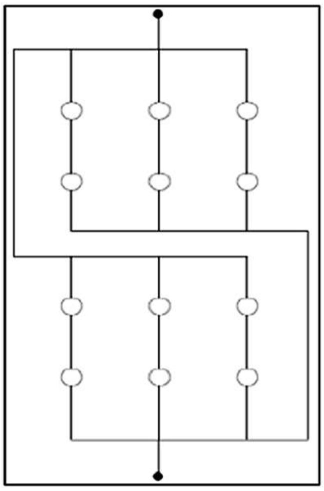

Figure 10.3. Arrangement of piezoelectric
Source: own elaboration.

Figure 10.4 illustrates how the prototype looked after its assembly on a 24 × 20 × 2cm Styrofoam plate.

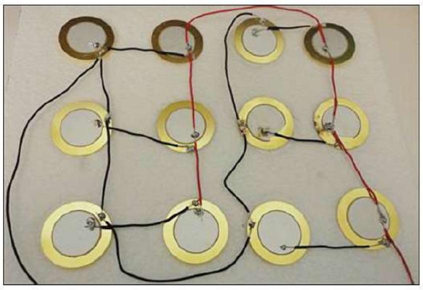

Figure 10.4. Final configuration
Source: Leiras *et al.*, 2014.

After having the final configuration of the piezoelectric, the same will be placed on a carpet, composed of a layer of vulcanized natural rubber, a layer of elastic springs, a layer of piezoelectric and again a layer of natural rubber (Figure 10.5).

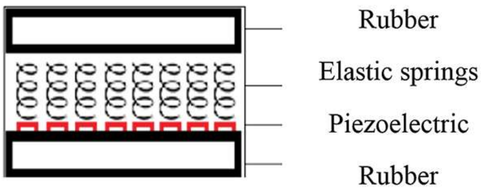

Figure 10.5. Carpet scheme
Source: Leiras *et al.*, 2014.

Figure 10.6. ESTG-IPVC's main entrance: a) location of the carpet with the respective piezoelectric; b) location of emergency exit lighting

Source: Leiras *et al.*, 2014.

The carpet it will be placed at the main entrance of the ESTG-IPVC (Figure 10.6). The movement of people will cause a vertical pressure on the carpet surface, resulting from their weight and speed. Once pressed, the power generator converts that pressure into energy, which in turn, after being duly rectified to direct current, is transmitted to some batteries. This stored energy will be distributed and applied to the school's emergency lighting.

3. Research results

Through the analyses carried out during the tests, it was verified that there are many, and with great sensitivity, the variables that influence the performance of the system. In general, a lot of difficulties were found in working with piezoelectric, mainly because there was little familiarity with this material. Finally, with the appropriate piezoelectric, it was possible to perform the tests satisfactorily and consistent results appeared. However, advanced engineering is required to optimize circuit performance. This may be one of the reasons why this type of application is not so widespread. Additionally, the low performance of the system makes the return-on-investment period high. It is also evident that the way of assembling the circuit for capturing energy becomes impractical regarding loads of considerable sizes, given its low efficiency. The piezoelectric material already has several applications, but much research is still needed so that its use as a converter of mechanical energy into electrical energy becomes commercially viable.

3.1. Project B

Project B consists of the development of a remotely controlled device, whose function is to monitor and control the electrical networks of ESTG-IPVC buildings. The chapter begins by exploring the concepts of Domotics and the Internet of Things (IoT), followed by a description of the proposed system operation and prototype. At the end the results are discussed.

Domotics and IoT

The term Domotics came from the junction of the word “Domus” which means house, with “Robotics” which performs actions automatically. The term emerged in the 1980s in France, during the construction of the first buildings, when man felt the need to look for new solutions for carrying out his daily and routine activities, aiming at quality of life, comfort, safety, and communication. The term is also known as: “Smart House”, “Smart Building”, “Smart Environment”, among others. Home automation has been used more and more in recent years due to the advantages that the associated technology offers. It is worth emphasizing that with the arrival of IoT (new and improved devices such as relays, microprocessors, and sensors), home automation underwent significant changes in terms of equipment quality, as they did not require large and reserved spaces, they began to be able to interact with other equipment and did not need constant maintenance by technicians. It allows and facilitates efficient management of installations and equipment; an automatic thermal control; information on the state of the installations; better energy efficiency; increased security in homes; lighting control with automatic adjustment scenarios depending on ambient light intensity The objective of home automation is that, through an integrated system, it is possible to control and automate the functions of all the electronic and electrical equipment in the house (Pimparel, 2017).

The term Internet of Things (IoT) emerged in 1999, when British specialist Kevin Ashton from the Massachusetts Institute of Technology (MIT) went to lecture at Procter & Gamble (P&G). Initially, he proposed that if connected objects were able to perform tasks without human intervention, it would be possible to optimize various activities. IoT emerged from advances in various scientific areas such as microelectronics, telecommunication, and information technologies. The main characteristic of the IoT is the presence of a set of objects, sensors and electronic devices and communication that allow interaction between them through communication. IoT can still be applied in several areas and one of them is home automation, in which one of the main factors is the communication between devices inside the house (Nascimento, 2018).

System proposal and prototype

The control device installed in the electrical network is composed of an ESP8266-01 (Figure 10.7), which is responsible for all the processing of the device, through its integrated microcontroller. This microcontroller is responsible for controlling the sensors and actuators of the circuit, as well as the Wi-Fi connection. As actuators, the ESP8266-01 is integrated in a Relay module, which allows switching on or off the electrical lighting in the building's division. The device has an ACS712 as sensor. Its function is to check the status of the electrical lighting in the building, that is, whether it is on or off. The remote-control application used in this project is Blynk, which is responsible for the user interface. Through this application, for example, a building security guard can obtain real-time information on his mobile device about the status of the electrical lighting in each room of the building, as well as remotely control it.

The ESP8266-01 (Figure 10.7) is a low-cost module with good performance, being widely used in remote motorization, sensor network, robotics, home automation, among other applications (Nascimento, 2018).

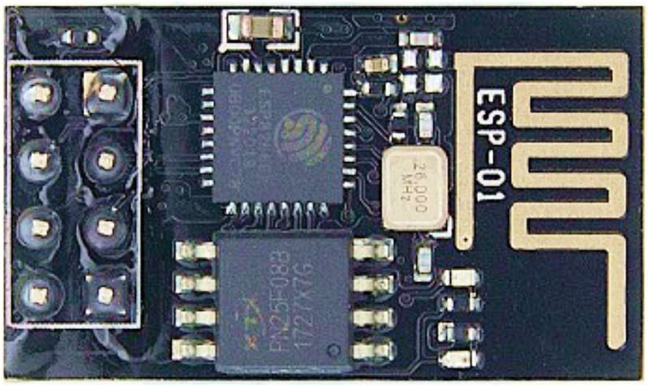

Figure 10.7. ESP8266-01 microcontroller
Source: own elaboration.

The Relay Module (Figure 10.8) is an electrically operated switch that allows switching on or off a circuit through voltage, supporting loads up to 250VAC and 10A, like a mechanical switch. The general supply of the module is 5V. A common regulator AMS1117 makes the regulation for 3.3V, for feeding the ESP8266-01. The Relay activates when the input reaches 5v and turns off when the input is 0v.

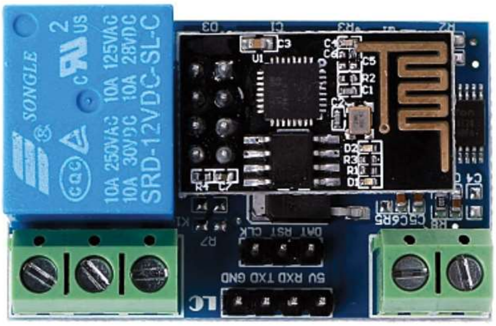

Figure 10.8. Relay Module with ESP8266-01 integrated
Source: own elaboration.

The ACS712 sensor (Figure 10.9) uses the hall effect to identify the magnetic field produced by a current passing through the circuit. It has an analogical output that varies linearly with current. It needs to be powered by 5V input voltage. Its voltage output signal will have the same frequency as the current it is measuring. This measurement makes it possible to calculate the value of electrical consumption in the network.

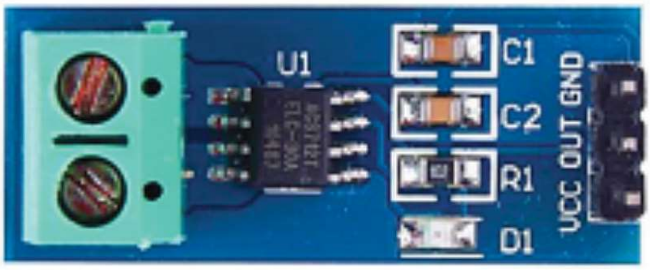

Figure 10.9. ACS712
Source: own elaboration.

Blynk is an application available for Android and iOS that allows the user to create applications that interact with the hardware. Through a specific space for each project, the user can insert Widgets that implement control functions (such as buttons, sliders, and keys), notification, and reading of hardware data. Communication between the application and the user's hardware is carried out through the Blynk cloud. The server is responsible for transmitting data to the hardware, storing application and hardware states, and storing sensor data read by the hardware even if the application is turned off (Introdução ao Blynk App, 2018).

The operation of the system is illustrated in Figure 10.10. The control device is installed at the entrance to the electrical supply for lighting in the building's room. The device is powered through a 230v to 5v transformer. Because the power supply of the Relay Module, like the ACS712 sensor, is 5V. The relay module has an integrated voltage regulator from 5V to 3.3V that supplies the ESP8266-01. Communication to the Wi-Fi Network is performed by the ESP8266-01. The network connection parameters are installed in the microcontroller, such as: the Wi-Fi network name, the network access word and the "AuthToken" (pairing code between the ESP8266-01 and the project created in the Blynk application). The lighting remote control is carried out through the Blynk virtual button, which initializes with the value "0" and when the user activates that button, it changes to the value "1". This information is sent through a virtual port to the ESP8266-01 and according to the value received (0 or 1), it gives the order to the Relay to activate or deactivate, sending the corresponding matrix with the hexadecimal codes. The Relay is installed in parallel with the division's mechanical switches, allowing the order to turn the lighting on or off both mechanically and remotely, without either of the two blocking the operation of the other. Monitoring the status of the lighting is done by the ACS712 current sensor, which identifies the magnetic field produced by the current passing through the circuit. As the sensor output signal varies between 0.5V and 5V and the ADC port of the ESP8266-01 only allows voltages up to 1V, it was necessary to install a voltage divider. The signal sent to the ESP8266-01 varies between very close values if the sensor does not verify current flow, and more distant values if there is current flow. The signal reading can be viewed graphically in the Blynk application, and this information is stored in the Blynk cloud, allowing the entire history of the behaviour of the electrical network to be viewed over time. The ESP8266-01 reads this signal for 5 seconds and records the maximum and minimum value verified during each sampling period and calculates the Delta (variation) between the maximum and minimum value. If the Delta value is 15, it means that the lighting in the room is on and in turn turns on the led.

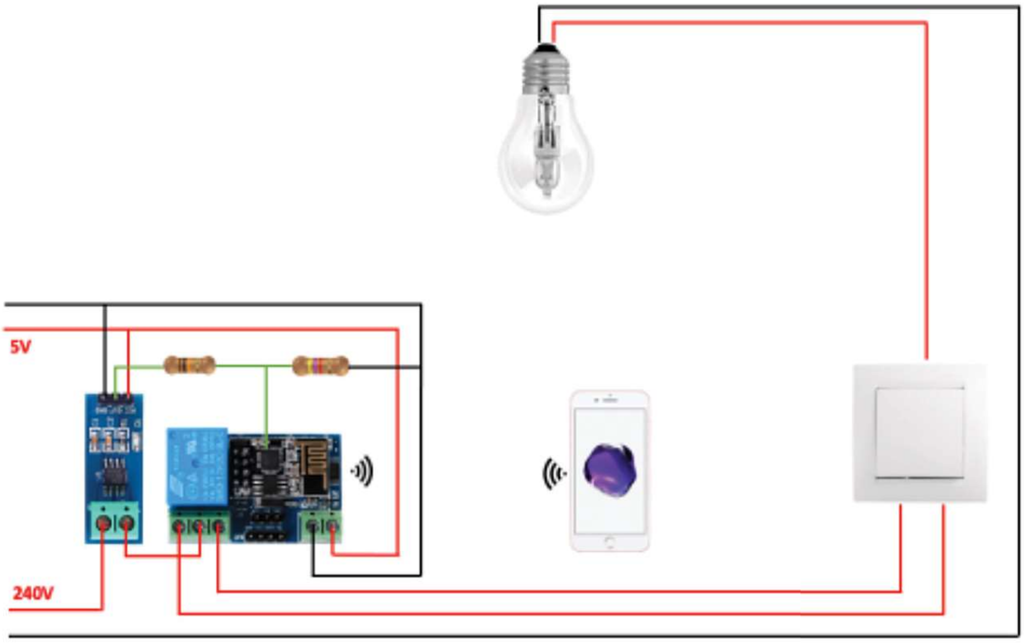

Figure 10.10. Scheme of the system developed
Source: own elaboration.

In Figure 10.11 we can see the prototype developed with this project. The prototype consists of the following components: 1 – 230v power supply; 2 – Power supply 5V; 3 – ESP8266-01 4 – Relay Module; 4 – Sensor ACS712 (20A); 5 – Breadboard with voltage divider; 6 – Mechanical switch; 7 – Lamp; and 8 – Smartphone with Blynk application.

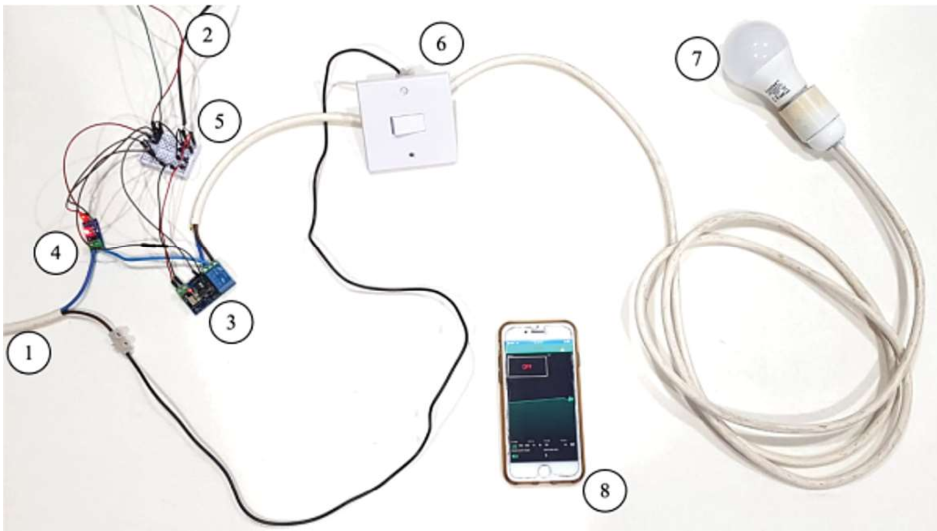

Figure 10.11. Prototype
Source: own elaboration.

In Figure 10.12 we can see that the circuit has the lamp turned off. If we look at the Blynk application, we can see that the state of the led is off, because the Delta value calculated by the microcontroller is 7, that is, the value is less than 15. We can also see in the graph that the values recorded are very close over time.

Figure 10.12. Result: lighting off
Source: own elaboration.

In Figure 10.13, we see that when we activate the Relay remotely, through Blynk's virtual button, the lamp turns on and automatically the virtual led too. The lamp turns on, because the Delta value calculated by the microcontroller is 22, that is, greater than 15. As we can also see in the application graph that the values recorded over time are more distant from each other.

Figure 10.13. Result: lighting on
Source: own elaboration.

3.2. Results discussion

With this project it was possible to create a device that enables remote monitoring and control of an electrical lighting network, supporting the reduction of electrical consumption in ESTG-IPVC buildings. Being an easy-to-install and low-cost device, it allows a short-term return on investment. However, through the various experiments, it was found that the potential of this device could be improved if the adopted microcontroller provided greater voltage tolerance.

Being a device with a high potential, future work can be developed that includes the measurement of energy consumption, in addition to the monitoring function. By exploiting the available resources of this device, it will be possible to carry out statistical analyses of the consumption and cost of electrical networks in buildings. The management of energy consumption will be more efficient if there is more information available on the electrical networks, as this is the only way to eliminate all waste.

4. Conclusion and recommendations

The present consumption and production patterns of developed countries, also aspired by those in developing countries, is recognised as unsustainable. ESD can help change behaviours and help citizens to carry out their collective environmental responsibilities and duties. HEIs have a critical responsibility in ESD since they provide the knowledge and skills for students to create sustainable development initiatives.

In this context, this study demonstrates the importance of ESD, as well as its effectiveness at IPVC, through the presentation of two projects developed by students from ESTG-IPVC, which intend to improve the energy efficiency in the institution. In the first project, a piezoelectric energy collection system was developed, to be applied on the school floor, taking advantage of the movement of people to produce energy. Despite the many difficulties in working with piezoelectric, mainly because there was little familiarity with this material, after several experiments and with the appropriate piezoelectric consistent results appeared. However, advanced engineering is required to optimize circuit performance before its implementation at ESTG-IPVC. In the second project, a remotely controlled low-cost device was developed, for remote monitoring and control of the electrical networks, enabling the reduction of electrical consumption in ESTG-IPVC buildings. Being an easy-to-install and low-cost device, it allows a short-term return on investment. However, to install it at ESTG-IPVC the microcontroller needs to be further exploited to include the measurement of energy consumption, in addition to the monitoring function. The management of energy consumption will be more efficient if there is more information available on the electrical networks, as this is the only way to eliminate all waste.

In conclusion, this work shows how students from a HEI with the Eco-School flag, in a classroom context and with the support of teachers, can be taught and motivated to develop sustainable solutions. In addition to environmental sustainability, these two projects simultaneously promote socio-economic sustainability, given the savings of financial resources in electrical energy, which can be applied to promote social welfare.

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