Photovoltaic Solar Energy. A Pedagogic Approach

JF Castro, J Carneiro, MFM Costa
Universidade do Minho, Portugal
mfcosta@fisica.uminho.pt

Abstract. The present work reports on a simple pedagogic exploration of a photovoltaic solar kit which aims to demonstrate the operation of a mobile orientable photovoltaic solar energy collection system employing a robot built with Lego parts.

Portugal is one of the European countries with the most favorable conditions for solar energy arnessing. It is therefore important to raise awareness and explain to young people across the country how photovoltaic panels work and the different and best ways to use them.

Although in Portugal the production of energy through photovoltaic systems is still relatively low, there is a strong growth potential also by the decreasing purchase prices, namely of silicon photovoltaic panels both polycrystalline and monocrystalline.

The need arises to include in the education of Portuguese students different aspects related to renewable energy. The use and exploration of the activity herein reported aims to contribute to this effort by making young students aware of how photovoltaic solar systems work.

With this demonstration students will explore how and how much electricity is produced by a photovoltaic solar panel and its dependence on the panel orientation the season and time of the day. We expect this type of activity to awaken in young people the interest and curiosity in the area of renewable energies so that in the future they can use, promote the use and contribute to the development of renewable energies and to our world's sustainable development.

Keywords. Solar Energy, Photovoltaic, Robotics.

1. Introduction

Fossil fuels are still unfortunately being used extensively for the most varied forms of generating energy [1]. However, as fossil fuels are exhaustible and very polluting there was a pressing need to create new, cleaner and preferently inexhaustible forms of energy production [1-4]. With this need, the so-called clean energies emerged, such as solar, wind, hydroelectric, among others [2].

Renewable energies have an increasingly important weight in energy production around the world. The sun, and solar energy, is one of the main sources of renewable energy that has seen a great growth in electricity production over the past few decades. Since solar energy is a natural and inexhaustible source it is one of the best existing energy alternatives. Photovoltaic solar energy [5] appears as a valuable alternative in the production of electrical energy through the use of photovoltaic panels that convert solar energy into electrical energy [6]. In recent years photovoltaic (PV) solar panels are being installed at an increasing pace worldwide. On figure 1 it is shown the evolution of the cumulative photovoltaic solar installed capacity in the world on last 20 years and the forecast until year 2050 [7].

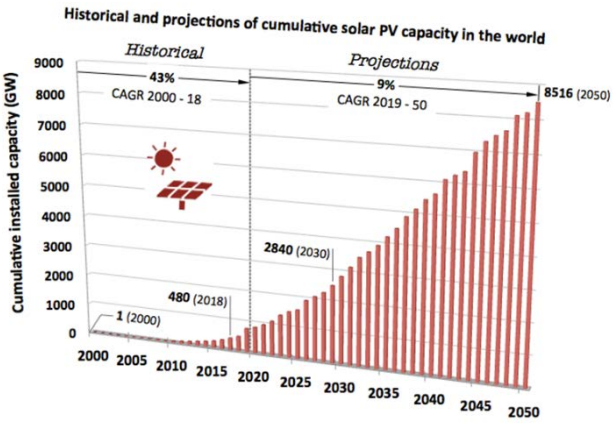

Figure 1. Historical values and future projections of cumulative installed solar PV capacity worldwide [1]

Photovoltaic solar energy brings several advantages, such as:

- It is an energy that does not pollute during its exploration;
- Solar radiation is abundant and free;
- Production plants require little maintenance;
- Panel technology is increasingly advanced, being increasingly efficient and more affordable;
- Solar energy is a good solution for places where there is no electricity grid.

However, using solar energy also has some disadvantages such as:

- Energy production is highly dependent on the meteorological situation;
- During the night there is no production which leads to the need of acquisition of energy storage means;
- In winter, many countries suffer from sudden drops in energy production;
- The forms of solar energy storage are inefficient when compared to other energies.

In Portugal the sun shines all year around for several hours each day. The average number of effective hours of sun in Portugal is of 7.2h. Of course, this number changes along the year been higher in the south of the country. However, the conditions are very good throughout the country and year in Portugal [8] (Fig. 2).

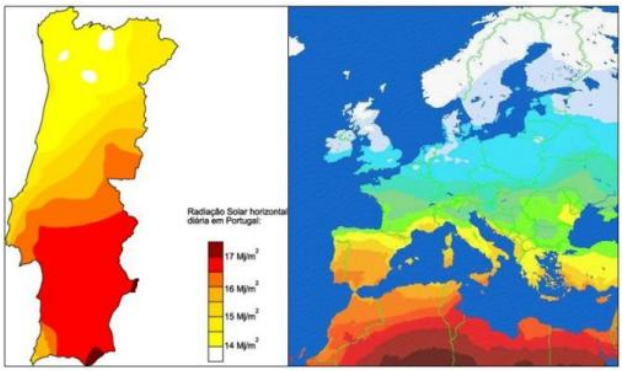

Figure 2. Average daily solar radiation in Portugal (NOCTULA, *Consultores em Ambiente*) [8]

2. Educational robotics

Educational robotics can be characterized by being an educational system that makes students to develop various skills in different areas through hands-on challenges [9].

This method can be considered a meaningful pedagogical tool, since a large majority of the students tend to more easily engage with the execution of experiments, thus actively processing information.

Practical experimental activities have long been one of the most effective ways to lead students to a successful science and technology learning [10-11].

Educational robotics has a multidisciplinary nature, which enables the development and implementation of a new technological culture, at the different levels of education, developing students' creativity through hands-on experimentation. Students can create and develop various types of robots that allow them to solve different problems and create multidisciplinary projects, thus highlighting one of the main objectives of tducational robotics[12] which is the creation of active learning environments based on student committed enrollment. It can be seen as a comprehensive tool, which can be used at different levels of education and as a way to address different content and which can be integrated into teaching from a constructivist perspective.

According to Antonio Valerio Netto [11], the main pedagogical advantages of robotics are:

- Develop reasoning and logic in the construction of algorithms and programs for controlling mechanisms;
- Favor interdisciplinarity, promoting the integration of concepts from areas such as: mathematics, physics, electricity, electronics and mechanics;
- Allow testing on physical equipment what they have learned using in theory or in “model” programs that simulate the real world;
- Transform learning into something positive, making the principles of Science and Technology very accessible to students;
- Encourage reading, exploration and research;
- Prepare students for group work;
- Encourage the habit of organized work, as it develops aspects related to the planning, execution and final evaluation of projects;
- Helping to overcome communication limitations, making students verbalize their knowledge and experiences and develop their ability to argue and counter-argue;
- Develop concentration, discipline, responsibility, persistence and perseverance;
- Stimulate creativity, both when implementing ideas and during the process of solving problems;

- Make the student aware of science in their daily life;
- Develop self-sufficiency in seeking and obtaining knowledge;
- Generate skills to investigate and solve real problems.

3. Robotics and solar energy

The use of robots and robotics to introduce solar energy in educational contexts is not new [10].

In this work an activitiy involving the use of components of LEGO [12-15] robotics kits is used to measure the amount of electrical energy produced by a PV solar panel depending on its orientation.

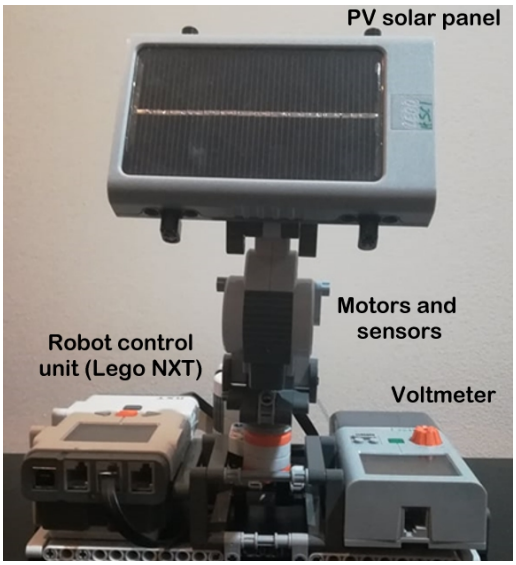

Figure 3. Robot controlled orientable photovoltaic prototype

It is well known that the amount of solar energy reaching the surface of the earth depends on many different factors including altitude and latitude. As well the number of hours of day light also changes along the year. In Portugal the number of hours of effective daylight varies roughly from slightly below 5 in December and January to well above 10 hours in June and July. The direction of illumination of sun light also depends on the hour of the day and on the location. Students know that by personal previous experience and can easily assess and confirm it using the mobile orientable photovoltaic prototype proposed for this work (figure 3).

The students can program the robot that controls the position and orientation of the PV solar panel to not only scan the different directions in order to optimize the solar energy collection at a particular instant but also to adjust that positioning along the day, the weeks and months on a particular location. The voltage generated by the photovoltaic solar panel can be registered to further analysis and or to give feedback to the robot. This first contact with artificial intelligence, even at a very basic level, is a valuable experience for the students.

4. Conclusions

Increasing the awareness and knowledge about sustainable development and the use of renewable energy sources among young people is crucial to our modern societies.

It is of utmost urgency to increase scientific literacy in these subject in our society. Working with younguer generations is fundamental.

To use hands-on investigative activities in interdisciplinary contexts may effectively engage students in an active commitment in learning about these subjects.

Adding the novelty of robotics and artificial inteligency to the study of the physics of electrical energy production with photovoltaic solar panels adds to the motivation of the young learners in creative and critical thinking education environments.

5. References

[1] S Shafiee, E Topal. When will fossil fuel reserves be diminished?. Energy Policy, 37(1), 181-9, 2009.

[2] MM Halmann, M Steinberg. Greenhouse gas carbon dioxide mitigation: science and technology. U.S.A: CRC press, 1998.

[3] C Koroneos, T Spachos, N Moussiopoulos. Exergy analysis of renewable energy sources. Renew Energy, 28(2), 295–310, 2003.

[4] P Schou. Polluting non-renewable resources and growth. Environmental & Resource Economics, 16(2), 211–227, 2000.

[5] A Goetzberger, J Knobloch, B Voss.

Crystalline Silicon Solar Cells, Wiley, New York, 1998.

[6] Sistemas Fotovoltaicos – Fundamentos sobre Dimensionamento. Joaquim Carneiro, Mário Passos. Engebook, 2020.

[7] IRENA, Global energy transformation: A roadmap to 2050, International Renewable Energy Agency, Abu Dhabi, 2019.

[8] http://noctula.pt/

[9] MFM Costa, JF Fernandes. Growing up with robots, Selected Papers on Hands-on Science. Costa MF, Dorrío BV, Michaelides P and Divjak S (Eds.), Hands-on Science Network, Portugal, 92-99, 2008.

[10] A Pereira, MFM Costa. Learning the Importance of the Sun as an Important Energy Source by Building "Solar Cars", Selected Papers on Hands-on Science II. Costa MF, Dorrío BV, and Michaelides P (Eds.), Associação Hands-on Science Network, Portugal, 433-436, 2017.

[11] Robótica na Educação, Antonio Valerio Netto, 2017. http://www.xbot.com.br/robotica-na-educacao/.

[12] CR Ribeiro, C Coutinho, MFM Costa. RoboWiki: Resources for Educational Robotics,, Selected Papers on Hands-on Science II. Costa MF, Dorrío BV, and Michaelides P (Eds.), Associação Hands-on Science Network, Portugal, 437-446, 2017.

[13] C Ribeiro, C Coutinho, MFM Costa. RobôCarochinha: um estudo sobre robótica educativa no ensino básico. V Conferência Internacional de Tecnologias de Informação e Comunicação na Educação, 210-223, 2007. http://repositorium.sdum.uminho.pt/bitstream/1822/6516/1/109.pdf.

[14] A Nagchaudhuri, G Singh, M Kaur, S George. Lego Robotics Products Boost Student Creativity in Pre-college Programs at UMES. Proceedings of the 32nd ASEE/IEEE Frontiers in Education Conference – session S4D, 2002.

[15] JB. Knudsen, "The Unofficial Guide to LEGO MINDSTORMS Robots", 1999.