Impact of cloud cover in the photovoltaic performance

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ÍNDEX

SUMMARY

This work is developed at the Oriented Secondary School Nº 241 "John F. Kennedy" in the town of Pujato, in the province of Santa Fe, Argentina.

The stimulus that motivates students to investigate and explore the impact of cloud cover in the photovoltaic performance was the presence of a solar panel in the institution. Faced with the approach of the topics Energy, its transformations and renewable energies, contents of the curricular space Physics, the relation between them and the solar panel appears quickly. A study emerges based on the following research question: *How does cloud cover affect the transformation of solar energy into photovoltaic on the solar panel installed in the Oriented Secondary School Nº 241 of Pujato, (Santa Fe) in the period between April 21st and October 13th, 2017?* that is answered by the hypothesis: "Cloud cover affects the performance of the solar panel so the recorded voltage is lower the greater the cloud cover."

A bibliographic survey is first started about: Renewable energies, their importance, solar energy, electromagnetic waves, behavior of light as wave-particle, photoelectric effect, electric field, photovoltaic cell, structure and operation of solar panels, photovoltaic effect, voltage, cloud cover, cloud types, Oktas measurement of cloud cover.

In a second stage the observation site of the sky is chosen, the school yard next to the solar panel. Within the GLOBE[1] Atmosphere Protocols, those related to the clouds are applied. The appreciation of cloud cover in Oktas and in percentages and the technique of voltage measurement are tested.

The daily observation (working days) of the sky and the voltage measurement are recorded, recording the results.

At the end of this stage, we proceed to the drawing of graphs showing the behavior of the variable cloud cover in Oktas and voltage, students discuss their assessments and considerations in a plenary corroborating the hypothesis.

Keywords: Solar Panel. Cloud cover. GLOBE Protocols. Photovoltaic performance

[1] GLOBE (The Global Learning and Observations to Benefit the Environment): International program, sponsored by NASA that promotes the learning and teaching of Science for the benefit of the environment. School 241 participates in this program with different protocols since 2004. Website: *www.globe.gov*.

INTRODUCTION

The Sun, source of life and energy that the human being has used since the beginning of history, can satisfy all our needs if we know how to rationally take advantage of the light that continuously sheds on our planet. This energy can be transformed into other useful forms of energy, for example, electricity. The use of this energy resource both for the generation of electricity and for thermal uses has numerous benefits that include, first, the reduction of emissions of greenhouse gases and other harmful gases that are associated with the use of polluting and exhaustible fossil fuels.

These benefits of solar energy as alternative energy are being exploited at the Oriented Secondary School Nº 241 "John F. Kennedy" (EESO 241) in the town of Pujato, in the province of Santa Fe, in Argentina (Figure 1) where recently a solar panel has been installed.

Figure 1: Pujato in America

This fact becomes a stimulus that encourages students in third year division B to start a school research work from the contents of the curricular space Physics since it is linked to the contents of this area. When dealing with the **topics** Energy, Energy Transformations and Sustainable Energies,

immediately the group of students relates solar energy with the presence of the solar panel installed in the school.

Interest in the **topic** increases curiosity about its functioning - transformation of solar energy into electrical energy - and the concern about the performance of this screen, if it is the same on totally clear days as on cloudy or partially cloudy days. Here comes the student's proposal to explore about the relationship proposed.

Information is sought regarding solar energy and in particular the voltage that the panel captures in order to link it with the cloud cover. In this way, the research question that guides the development of this study is posed.

Research Question:

How does cloud cover affect the transformation of solar energy into photovoltaic on the solar panel installed in the Oriented Secondary School Nº 241 of Pujato, (Santa Fe) in the period between April 21st and October 13th, 2017?

Hypothesis

Cloud cover affects the performance of the solar panel installed in the Oriented Secondary School Nº 241 of Pujato (Santa Fe) in the period between April 21st and October 13th, 2017 so the recorded voltage is lower the greater the cloud cover.

General objective

To study the relationship between cloud cover at the moment of measurement and the photovoltaic record of the panel installed in EESO 241 of Pujato (Santa Fe) during working days from April 21st to October 13th, 2017.

Specific objectives

- ✓ To define the next solar panel study site and from where the cloud cover will be observed.
- ✓ To know the different types of cloud cover that characterize the study site (33°1'6.65" south latitude and 61°2'30.65" west longitude)
- ✓ To apply GLOBE Protocols to estimate cloud cover at the study site.
- ✓ To record the voltage captured by the solar panel installed in EESO 241 from April 21st to October 13th, 2017.
- ✓ To interpret the data relating the photoelectric voltage recorded by the solar panel with the cloud cover observed at the study site during the time of measurement.

Relationship with curricular content

The present work is linked to the contents of the curricular space **Physics** in terms of: Physics as a science and its relationship with Technology, Measurement, Energy, Energy Transformations, Sustainable Energies and Electricity Notions. It is also linked to other spaces such as Geography in terms of definition of the study site and Cloud cover, and Biology within the framework of environmental care.

Theoretical framework

Solar energy is subject to continuous fluctuations and more or less sudden variations, so, for example, solar radiation is lower in winter, precisely when it is most often needed. However, South America presents a privileged situation, since about 1,500 kilowatt-hours of energy per year per square meter of soil, can be used directly or converted into electricity. Man has tried to take advantage, by all possible technical means, of this free, clean and inexhaustible energy source.

When looking for information about this type of energy and all the transformations that solar energy makes possible, one should focus on the concepts of this study:

- Solar radiation: energy radiated from the sun in the form of electromagnetic waves.
- Electromagnetic radiation: Combination of electric and magnetic fields that propagate through space in the form of energy carrier waves.
- Wave-corpuscle duality: Light behaves as a wave and can produce interference and as a corpuscle or particle, in energy packages called photons. The energy of photons depends on the frequency of electromagnetic radiation.
- Electric field: It originates when an electrical charge modifies the properties of space. That is to say, the phenomena of attraction and repulsion that originates an electrical charge on other charges placed in their vicinity are described saying that around it there is an electric field. The electric field pushes the positive moving charges to one direction and the negative moving charges in the opposite direction.
- Electric current: flow or movement of electrons.
- Photoelectric effect: Emission of electrons by a material when an electromagnetic radiation hits it. It is the basis of the production of photovoltaic solar energy.
- Photovoltaic cell: Small cell made of crystalline silicon and / or gallium arsenide (semiconductors) that converts solar light directly into photovoltaic. These materials are mixed with others, for example, boron to give them a positive charge, then they are P-type

semiconductors (generates empty holes), or with phosphorus to give them a negative charge, then they are N-type semiconductors (they have a leftover of electrons).

If there are no charges, the cell does not generate electricity.

A photon can generate an electron-hole pair that in its movement generates an electric current. That is, when the crystalline cells charged positively and negatively, are exposed to the sun, the solar energy causes the electrons to move from the part of the cell that is left over (N) to the part of the cell that is missing (P) producing electrical current from one point to another. This is called photovoltaic effect.

- Solar panel: Set of positive and negative solar cells interspersed and fastened with a conducting wire. The whole set of cells causes an electric field to be produced.
- Voltage or potential difference: If there is an electric field there is an electrical potential associated with it, the electric field will point in the direction in which the potential decreases. It is a necessary electrical gap so that an electric current can flow and the unit of measure is the Volt.
- Tester: Instrument for measuring electrical quantities that allows to determine, in a wide range of values, the difference of potential or voltage between two chosen points of the circuit, both for alternating and continuous current, among other functions. The digital tester allows reading the magnitude in a liquid crystal viewer.
- Console associated to the panel: It presents 2 terminals on its left side where the end needles of the tester cables are applied which allow reading the voltage delivered by the solar panel. This console also has two other terminals on its right side, which are already regulated voltage output to charge batteries.
- Clouds: The World Meteorological Organization (WMO) defines cloud as a "hydrometeor consisting of minute particles of liquid water or ice, or of both, suspended in the atmosphere and usually not touching the ground. It may also include larger particles of liquid water or ice, as well as non-aqueous liquid or solid particles such as those present in fumes, smoke or dust."
- Cloud cover or cloudiness: it is the fraction of the celestial vault that is covered with clouds.
- Okta: is the unit of measurement of the cloudiness, which corresponds to the eighth part of the celestial vault.

Next, Table 1 is shown indicating the scale used to encrypt the cloud cover, the symbol and the corresponding denomination. The same has been obtained from the website *http://www.lineaverdemijas.com/lv/consejos-ambientales/las-nubes/cantidad-de-nubes.asp*:

Table 1: Symbols to indicate the cloudiness

In the GLOBE Program and according to the Atmosphere Protocols, cloud cover is reported by grouping percentages:

FEW: From 0% to 10% 0 Oktas

ISOLATED: From 10% to 25% 1 and 2 Oktas (1/8; 2/8)

SCATTERED: From 25% to 50% 3 and 4 Oktas (3/8; 4/8)

BROKEN: From 50% to 90% 5, 6 and 7 Oktas (5/8; 6/8; 7/8)

OVERCAST: From 90% to 100% 8 Oktas (8/8)

Table 2 shows the aforementioned in another format:

Table 2: Cloud coverage information

Oktas	Corresponding Percentage	Name according to GLOBE
0	0 %	Few
1	12,5%	Isolated
2	25%	Isolated
3	37,5%	Scattered
4	50%	Scattered
5	62,5%	Broken
6	75%	Broken
7	87,5%	Broken
8	100%	Overcast

- Types of clouds: According to its altitude and forms: High clouds: cirrus, cirrocumulus, cirrostratus. Average clouds: altocumulus, altostratus. Low clouds: nimbostratus, stratocumulus, stratus, cumulus, cumulonimbus. The most common in our area are: stratus (cloudy days), stratocumulus (present when it rains) and cumulonimbus (in thunderstorms).
- Direct solar radiation: Solar radiation that arrives directly on the solar panel without any interference.
- Diffuse solar radiation: Solar radiation to which it is placed a cloud or clouds - mists in its path to the solar panel.
- Clinometer: Tool to measure angles that allows calculating indirectly the height of poles, trees, building.

It should be noted that the different types of clouds do not develop in depth in the present theoretical framework because they do not make the end of this research work. However, it is one of the topics that most appeals to the research group, showing enthusiasm for direct observation and their recognition.

It is important to note that this research is interesting because it develops ideas related to the environment where the study is conducted, which is the school itself and the devices installed in it that are related to energy, in particular the solar panel. At the same time, the connection made between the observations of the sky and the measurements corresponding to the photovoltaic energy is important; both variables related to the terrestrial environment.

MATERIALS AND METHODS

- ***Initial dialogue on Sustainable Energies***

The present work begins with a teacher dialogue on Energy, its transformations and the use of renewable energy in the face of the urgent need to face the problem of environmental pollution. Students participate with knowledge they already have and their own experiences, emphasizing the importance of the awareness of all human beings facing this problem. The role of science and technology in the research and development of products that provide possible solutions to these issues is highlighted.

- ***Bibliographic survey***

Given this concern, it is proposed to conduct a bibliographic search, internet material, scientific journals, newspapers, reports of work from previous years and any relevant material provided by students on the following topics:

1. Renewable energy. 2017 "Year of Renewable Energies".
2. Solar energy. Electromagnetic waves.
3. Photoelectric effect. Wave-corpuscle duality.
4. Sunscreen. Its structure and materials that compose it. Chemical reasons of the choice of those materials. Manufacturing control standards.
5. Location and orientation of the school screen: angle, latitude and longitude.
6. Direct solar radiation and diffuse solar radiation.
7. Cloud cover. Types of clouds. Can the sky be measured? Measurement in Oktas and percentages.

The activity is carried out by work groups after completing the information search stage, socialize what has been researched through explanations, illustrations, graphics, posters, and the elaboration of summaries that are shared.

- ***Technical talk by a specialist (STEM)***

A visit was received from Mr. Alejandro Lambertucci, a specialist in solar panels, which lasted for 80 minutes tackling different points such as the importance of renewable energies, photovoltaic cells, the photoelectric effect, the angle and orientation of the solar screen installed in the school, voltage, energy used in the manufacture of solar screens and their effect on the environment, IRAM

standards, installation of screens in homes according to the consumption of each household, storage of photovoltaic energy in accumulators and batteries, possibility of enriching the public electricity network, utility of solar screens in areas far from urban centers, photovoltaic energy in the future. The students ask many and varied questions that are answered by the technician with clarity. The students appreciate his presence and time dedicated to them.

- ***Observation of the sky***

In the next stage we proceed to the direct observation of the sky from the courtyard of the school, for the recognition of its status, solar radiation and different types of clouds. The estimation of cloud cover in Oktas and its expression in percentages at the time of observation is tested.

- ***Choice and definition of the study site***

It was decided to carry out the work in the vicinity of the solar panel that is installed on the roof, in front of the building of EESO 241 located in Simón de Iriondo 747, Pujato, province of Santa Fe (Figure 2).

Figure 2: View of the front of the EESO 241 where the solar panel is installed

It is decided to observe the sky in the school yard, where students usually spend time and sometimes perform other activities. The place becomes the **study site** where this school research will be carried out.

Therefore, the coordinates are established using *Google Earth*[2] online, they are: Latitude: 33°1'6,65" S and Longitude: 61°2'30,65" W (Figure 3).

Figure 3: Satellite image of Google Earth where the study site is located

To define the site, the guidelines of the GLOBE Program are followed, in this way the place where the observations are made is characterized, in this case the yard. It should be noted that both the floor and the walls that surround it are made of material. There are no trees or bare floor surface. In the following photograph you can see the surface paved with tiles (Figure 4).

Figure 4: View of the site with the surface of the tiled floor

[2] Google Earth online: https://www.google.com/earth/

- ***Determination of obstacles that prevent the vision of the sky and that is part of the characterization of the study site***

Since the observation that will be made is the sky - the cloud cover and the type of clouds - it is important to take into consideration the obstacles that hide part of the sky. These obstacles, according to the protocols of the GLOBE Program corresponding to the Atmosphere, are determined not only by measuring the angle under which the walls surrounding the yard are observed but it is also established that objects from above an angle of 14° of elevation do not allow the wide view of the sky. For this reason, Ms. Maria Selene Jandiriz, who serves as GLOBE Alumni, is present at the school to collaborate with the students and to establish these obstacles. To this end the students use a clinometer[3], built by them, to measure these angles (Figure 5).

Figure 5: Student assembling the clinometer and testing it on the site

Students measure the angles under which the walls surrounding the yard are observed as shown in Figures 6 and 7

[3] Instrument used to measure the angle from the vertical of objects such as walls, towers, poles, trees. The measurement is expressed in sexagesimal degrees.

Figure 6: Measurements to the West

Figure 7: Measurements to the East

From the measurements made it is observed that all the walls surrounding the yard obstruct the view of the sky because they exceed 14 °, except for three small sectors, that of the south zone, behind the flag, which can be seen in Figure 7 where the students are measuring to the east, in the background you can see the wall mentioned; the other two sectors are: the one located in the northwest corner and the east wall that surround the yard (Figure 8) and the wall of the west-northeast corner (Figure 9), which are shown in the following photographs:

Figure 8: Northwest - East corner

Figure 9: West – Northeast corner

With this data, the students have defined the site on the GLOBE Program website, included in the place assigned by EESO 241. There the site is named as "NUBES 241", as can be seen in Figure 10:

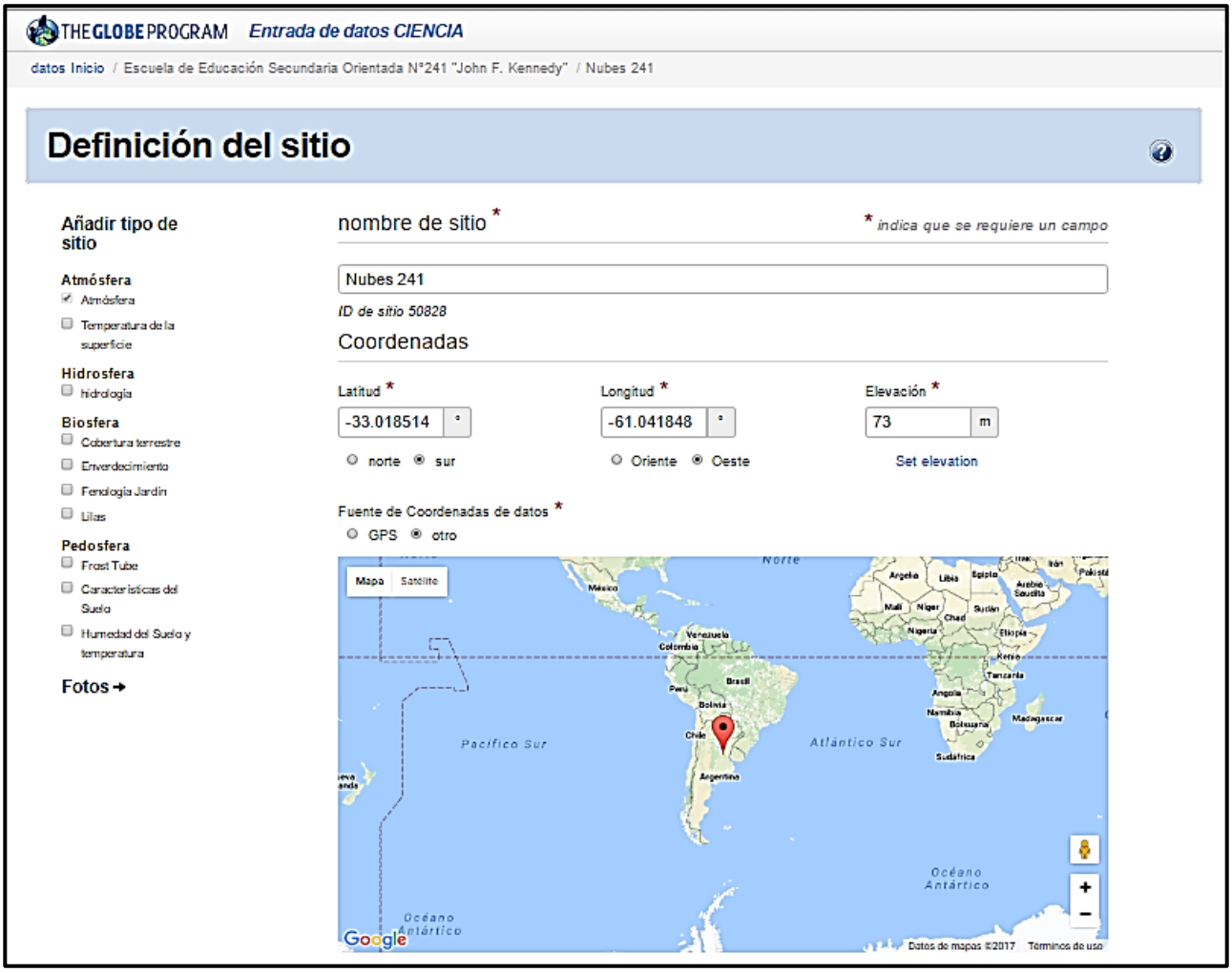

Figure 10: Definition of the GLOBE site

- ***Test of voltage measuring technique***

Previous tests are carried out on the technique of voltage measurement with the orientation of Mr. Alejandro Lambertucci, installer technician of the solar screen, in contact with the teacher. The measurement technique consists of selecting the DCV (direct current voltage) function in the 20 position using the tester's selector switch, then inserting the red and black cable needle into the correct console pin (each plug is the same color that the corresponding cable, the pins indicate the points between which the potential difference exists), and immediately the result of the measurement arises.

- ***Table for data logging***

Based on all the information, the group proceeds to create a data record table (Table 3). There is a dialogue in class about what the measurement days will be, agreeing that they will be business days

due to the difficulties and doubts that the students present during weekends and holidays for family, sports, distance or climate reasons. The end of the school day is chosen as the measurement schedule.

Table 3: Data record

N”	Day of the week	Date	Solar Radiation	Type of clouds	Coverage Symbol	Cloud cover (everyday expression)	Voltage captured by the solar panel	Registration schedule

- ***Data logging***

In accordance with the objectives set and in the attempt to solve the research problem that guides this research work, students proceed daily to record the photoelectric voltage captured by the solar panel, not only using the tester but also observing the clouds at the time of registration, either the cloud cover or the cloud type. In the following photographs (Figures 11, 12, 13 and 14) the students are shown performing these activities:

Figure 11: Measurement of Voltage captured by the Solar Panel

Figure 12: Written record of the photovoltaic voltage

Figure 13: Observation of the sky

Figure 14: Written record of cloud cover and type of clouds

- ***Data entry to the EESO 241 website within the GLOBE Program***

The data is uploaded by the students via web (*www.globe.gov*), corresponding to the EESO 241 "John F. Kennedy" (*https://www.globe.gov/web/240911*). In particular, the records are completed and reported by the students in "Nubes 241": Date, time of observation, state of the sky (clear, cloudy or in the dark) indicating percentage of cloud cover; colour and visibility of the sky; surface conditions; type of clouds and voltage captured by the solar panel installed in the school. Some of these data are not used in the present work, nevertheless the information required from the GLOBE Program is completed for a study site of this type (Figures 15 and 16).

Figure 15: Students uploading data via the web to the GLOBE Program

Figure 16: Screenshot of the study site "Nubes 241" when uploading the data

- ***Data analysis***

1) The data of the variables are tabulated taking into account the date on which the registration is made. As for the cloud cover, it is expressed in Oktas, taking the values from 0 to 8. The solar radiation is indicated as direct or diffuse, as they reach or not to the surface the Sun's rays, with the values 0 or 1 respectively. The electric potential is expressed in Volts (V).

2) Extreme values and statistical measures of the electric potential variable are calculated.

3) Graphs are constructed to relate the variables: Ratio of the cloud cover in function and the photoelectric potential captured by the solar panel throughout the days; trends in cloud coverage and photoelectric potential and photoelectric potential vary depending on the type of direct or diffuse radiation.

4) Distributions and trends among the variables are studied.

- ***Connection to STEM Professionals***

The students visit the Institute of Physics of Rosario of the National Council of Scientific and Technical Research (IFIR / CONICET). The STEM professionals, José Pomar, Meteorological Observer, and Federico Mateo, Systems Engineer, provide guidance on cloudiness, cloud types and, in particular, on the capture of energy through solar panels. In addition, they support the students and collaborate in the interpretation of the data collected, deepening and improving the analysis of the results of the research.

RESULTS

It is important to mention that, when expressing the results of the measurements, the errors inherent in the cloud cover must be taken into account, since the measurement by Oktas require a lot of practice.

In turn, the registration with the tester can also incorporate measurement errors that depend both on the observer and on those derived from the instrument used; the first one, which depend on the observer, decrease with practice, however, they affect each variable and in turn the relationship between them.

Below, the records are presented, clarifying that during the month of June no measurements were taken due to technical problems and, in the first three weeks of July, no measures were obtained because the students were not at school due to the winter break.

Two tables are shown corresponding to the first stage (Table 4), prior to the zonal instance of the Science and Technology Fair that was held in June 2017 and the second (Table 5), after the winter break, which ended on the 21st July 2017. However, this organization in two tables to visualize the data, the analysis is done jointly.

Table 4: Data until June 2017

Date	Cloud cover (Oktas)	Solar radiation Direct (0) or Diffuse (1)[4]	Electric Potential (V)
21/04/2017	1	0	19,58
24/04/2017	8	1	19,50
25/04/2017	8	1	18,07
26/04/2017	0	0	20,50
27/04/2017	0	0	20,02
28/04/2017	0	0	19,94
02/05/2017	2	1	19,94
03/05/2017	4	0	19,40
04/05/2017	0	0	19,60
05/05/2017	2	0	19,60
08/05/2017	4	0	19,95
09/05/2017	0	0	19,57
10/05/2017	8	1	19,89

Table 5: Data after July 21, 2017

Date	Cloud cover (Oktas)	Solar radiation Direct (0) or Diffuse (1)	Electric Potential (V)
24/07/2017	2	0	19,89
25/07/2017	8	1	20,40
28/07/2017	2	1	20,10
31/07/2017	8	1	19,60
01/08/2017	8	1	19,04
02/08/2017	1	0	19,54
03/08/2017	0	0	20,50
04/08/2017	0	1	20,40
07/08/2017	8	1	19,20
08/08/2017	0	0	19,85
09/08/2017	8	1	20,05
10/08/2017	8	1	20,03
11/08/2017	8	1	18,76

[4]Number zero is chosen to represent the direct solar radiation indicating that part of the solar rays are not obstructed by the cloud cover and number one to indicate that the solar rays arrive diffusely.

11/05/2017	8	1	19,86
12/05/2017	8	1	18,85
15/05/2017	8	1	19,83
16/05/2017	4	0	20,10
17/05/2017	7	1	19,92
18/05/2017	8	1	19,52
19/05/2017	8	1	20,00
22/05/2017	0	0	20,10
23/05/2017	2	0	19,90
24/05/2017	8	1	18,80
26/05/2017	3	0	19,95
29/05/2017	5	1	19,53

14/08/2017	0	0	20,60
16/08/2017	0	0	20,00
25/08/2017	8	1	19,06
28/08/2017	8	1	19,37
29/08/2017	8	1	18,83
30/08/2017	3	1	19,91
01/09/2017	8	1	19,90
04/09/2017	0	1	20,01
06/09/2017	1	0	20,50
07/09/2017	8	1	18,87
10/09/2017	8	1	20,00
12/09/2017	0	0	19,93
13/09/2017	0	0	19,46
14/09/2017	0	0	19,34
15/09/2017	6	0	19,73
18/09/2017	0	0	19,88
20/09/2017	6	1	19,75
22/09/2017	0	0	19,70
29/09/2017	8	1	20,50
02/10/2017	0	0	19,79
03/10/2017	0	0	19,30
04/10/2017	8	1	20,20
05/10/2017	1	1	19,67
06/10/2017	0	0	19,71
09/10/2017	0	1	19,33
10/10/2017	6	1	19,74
11/10/2017	8	1	19,45
12/10/2017	8	1	20,40
13/10/2017	3	0	19,77

With these results each student makes a graph manually in a millimeter sheet, relating the cloud and voltage variables.

In this activity, the students study the measurements, comments, appreciations, memories of the measurement process, all of them greatly enrich the exploratory work.

In turn, Microsoft Excel Software is used, which allows students to prepare tables, formats that include mathematical calculations using formulas, especially statistics and graphs with which they will enrich the discussion of the results.

The graphics obtained, similar to those made by the students in millimeter sheets, can be visualized in the following page, given the size of them they are placed in a horizontal way (Figures 17 and 18) to facilitate their reading.

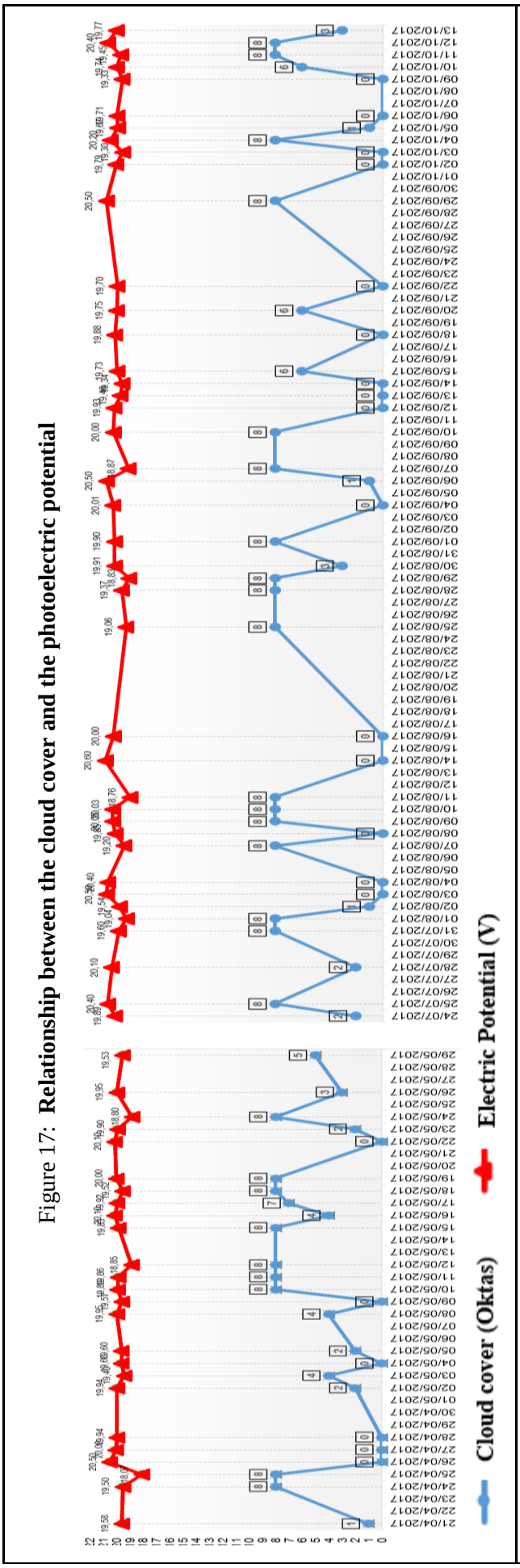

Figure 17: **Relationship between the cloud cover and the photoelectric potential**

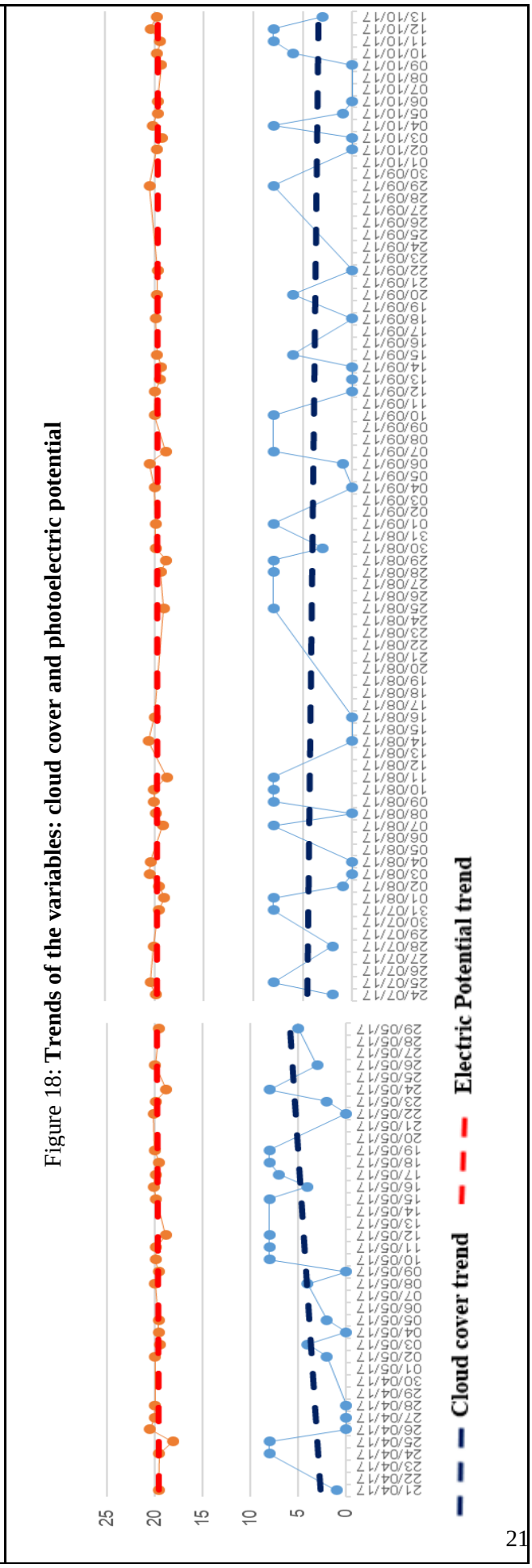

Figure 18: **Trends of the variables: cloud cover and photoelectric potential**

The previous page shows two graphs, the *Ratio of cloud cover and the photoelectric potential captured by the solar panel* over the days (Figure 17) and in the other *Trends in cloud coverage and the variation registered photoelectric potential* (Figure 18). In each of them, it is shown that during the periods of June and July measurements were not recorded.

With the Microsoft Excel Software application, some statistical values that characterize tabulated records are also calculated. The values, which may be representative of the data recorded as a whole, are the following:

Electric potential:

- ✓ Average: 19.75 V
- ✓ Standard deviation: 0.48 V
- ✓ Maximum value: 20.60 V (08/14/2017)
- ✓ Minimum value: 18.07 V (04/25/2017)

When relating the average and standard deviation applied to the electrical potential, it is possible to affirm that the value is representative of this data.

When observing the first graph (Figure 17), which corresponds to the *Ratio of the cloud cover and the photoelectric potential captured by the solar panel*, it is possible to visualize that the largest quantities of photoelectric potential measurements are observed around 20V while the variability of the cloud cover is recorded between 0 and 8. These observations are reaffirmed in the second graph (Figure 18) where the trend of the photoelectric potential is represented by a horizontal line, around 20V, which indicates that there are no variations.

With the use of Excel it is possible to group the values of the photoelectric potential captured by the solar panel in relation to solar radiation, direct or diffuse. In that case, the following graph (Figure 19) shows how the records are grouped:

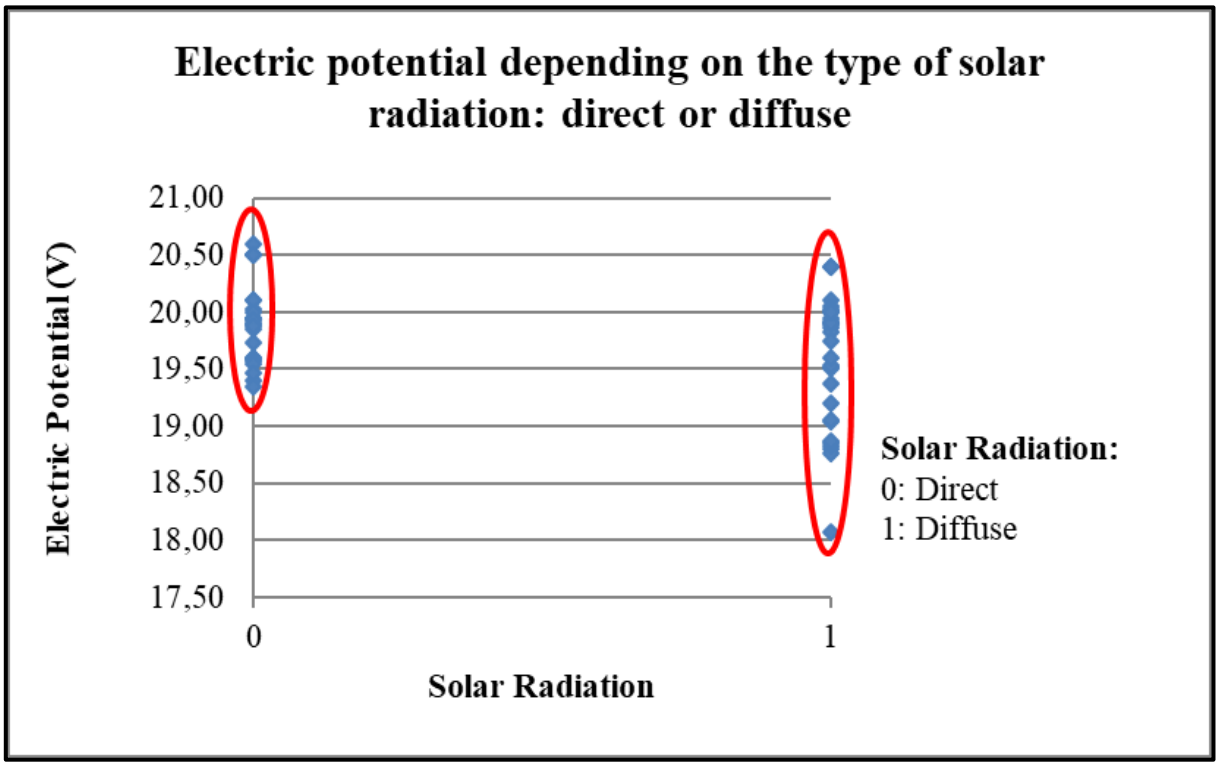

Figure 19: Relationship between the photoelectric potential and the type of radiation -direct or diffuse-

At first glance it can be observed that the points corresponding to direct radiation are slightly higher than those of the days with diffuse radiation. To compare these values, we calculated the average of the photoelectric potential during some days with direct solar radiation and for those with diffuse radiation, obtaining 19.86V and 19.64V respectively.

DISCUSSION

From the observation of the records and from the graphs obtained it is possible to affirm that while the cloud cover fluctuates between 0 and 8 Oktas, which correspond to clear and covered skies, respectively, the photoelectric potential captured by the solar panel assumes values close to 20 V, on average 19.75 V, with a maximum value of 20.60 V and a minimum value of 18.07 V. If these two characteristic values of the registered maximum and minimum photoelectric potential distribution are taken into consideration, it is possible to observe the complete records of the day on which each value is produced. In this case, it is verified that on 08/14/2017, when the maximum occurs, it corresponds to direct solar radiation with total absence of clouds (0 Oktas) while on 04/25/2017, when the minimum occurs, the radiation solar is diffuse and the cloud cover is total (8 Oktas).

Regarding the relationship between direct or diffuse solar radiation at the time of recording and the photovoltaic potential captured by the solar panel, it is possible to compare the averages calculated

on page 14 and observe what is reflected visually in the graph of that page, to affirm that for the measurements made, when the solar rays are not totally covered by clouds, the registered photoelectric voltage is slightly higher (on average 19.86 V) than when the radiation arrives indirectly (on average 19.64V).

When analyzing the data obtained, it is determined that, during clear days, the voltage is slightly higher than that registered when the sky is totally cloudy, so it is possible to observe, that when the coverage increases the photoelectric voltage captured by the solar panel, decreases slightly. In other words, when there is presence of clouds the radiation is affected and manifests itself in a lower photoelectric potential

A very important observation that is put into discussion is the fact that throughout the records season changes have occurred (autumn - winter - spring) and this had no impact on what was investigated.

The research group believes it is important to clarify in front of the problem that arises and is expressed in the socialization during the regional fair, the influence of the type of cloud on photovoltaic performance is beyond the scope of this investigation at this time, since this work makes reference to the impact of cloud cover in general on photovoltaic performance. It can be an object of investigation for a future project. Although during all the work the type of cloud present during the observation is taken into account, this responds to the desire of the students (included in the specific objectives for that reason).

CONCLUSION

Based on all the research work carried out and in response to the problem: How does cloud cover affect the transformation of solar energy into photovoltaic on the solar panel installed in the Oriented Secondary School Nº 241 of Pujato, Santa Fe, in the period between April 21st and October 13th, 2017? it has been possible to verify the existence of a relationship between the registered variables and a slight tendency by which it is possible to affirm within the data obtained that the hypothesis stated *"Cloud cover affects the performance of the solar panel so that the registered photoelectric voltage is lower the greater the cloud cover "* has been corroborated.

To perform a more forceful test, a greater number of measurements would be required; since the series of data is limited - few records to obtain a solid conclusion - in order to determine what type of regularity links to both variables it is necessary to continue with the measurements, with seasonal and meteorological studies that complement and describe this study; including more frequent measurements throughout the day.

PROJECTION

Possible ways to continue the present project in 2018:

- Students send the cloud coverage information to the GLOBE Program, and in mid-September another NASA program, the S´COOL[5] joins the GLOBE cloud protocols. The S'COOL Project compares the records of cloud cover observed from Earth, recorded in GLOBE, with data from some of NASA's satellites (CERES: Calypso, Terra, Acqua, GEO or NPP) when their observation is in the period of overflight of the satellite. Then the participants will receive a "correspondence" comparison email. As an example, one of the images received recently is shown (Figure 20), which corresponds to the observation of August 28th, 2017 and its comparison with the GEO satellite record. The observation from Earth is on the left, in this case the students had reported cloud cover greater than 90% with low clusters and the observation of the satellite and images are on the right, in this case the satellite coverage gives 100% cloud cover with low and medium clouds.

In this particular case (Figure 20), it can be deduced that from the surface they have not been able to observe "the thickness" of the total cloud layer. This comparison opened a new possibility of projecting the work, relating the photoelectric potential captured with the cloud cover registered by one of the NASA satellites that fly over the site on a daily basis, prior knowledge of the overflight schedules, records and observations. This is an interesting projection that the research group is planning for 2018 because they think the relationship may have more precision when observing from above because it is possible to estimate the "thickness" of the cloud layer, while from the Earth there is not such appreciation.

[5] The S'COOL Project involves participants, making and reporting ground observations of clouds to assist in the validation of NASA's CERES satellite. Website: *https://scool.larc.nasa.gov/GLOBE/*

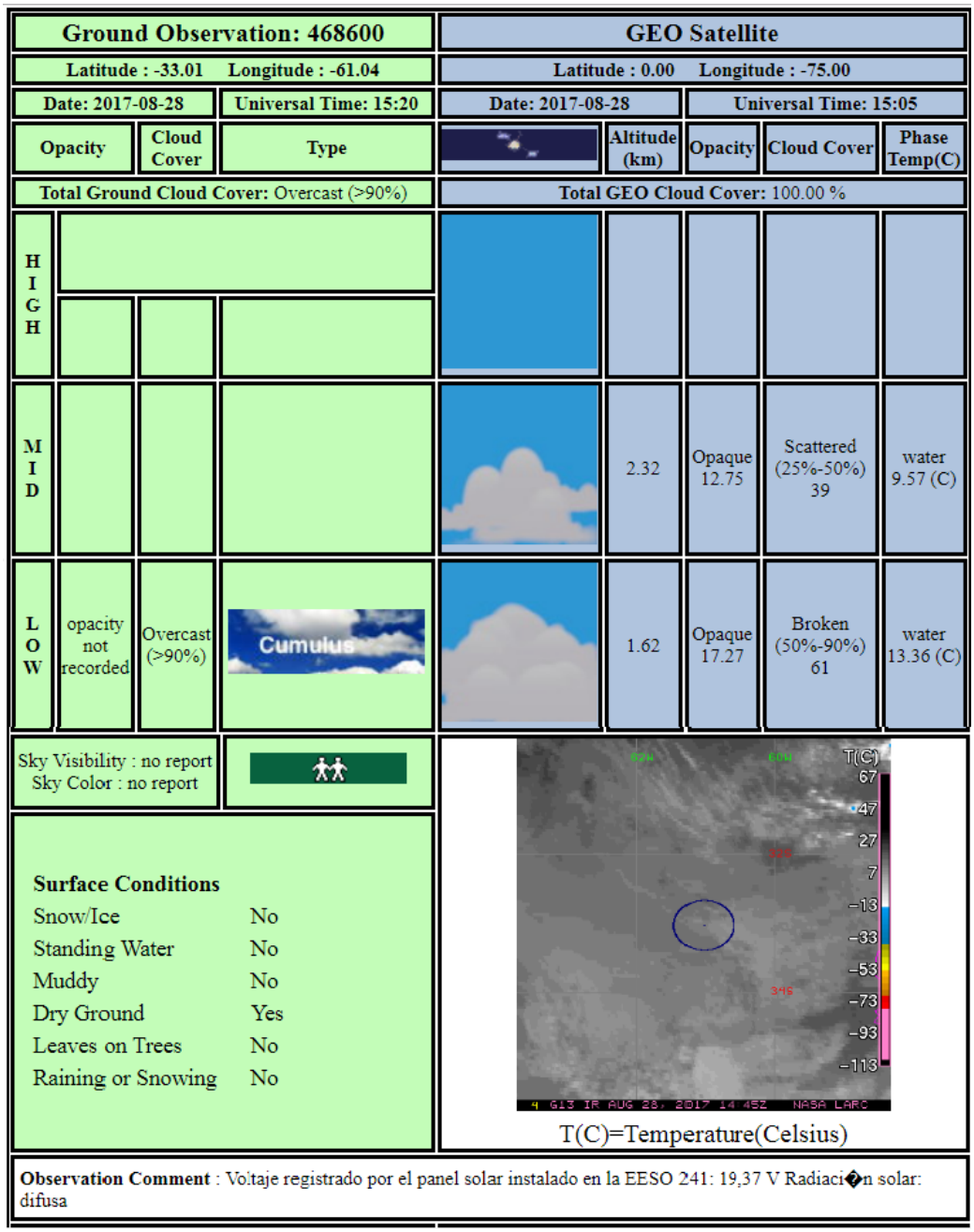

Figure 20: Observation of the day August 28, 2017 and its comparison with the GEO satellite

- Following the previous figure, in it you can see a satellite image that can be expanded with details and find more information about the detected cloud layer, in relation to height and temperature, among other features. These data could also give rise to some kind of projection of the present work, relating the photoelectric potential captured by the solar panel in relation to the characteristics described in the satellite images of the recorded cloud cover on the location of the site. In this case, the research will be enriched with the study of satellite images.
- In addition, this work could be projected in the study of the possibility of measuring photovoltaic solar energy accumulated in batteries or accumulators.

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GRATEFULNESS

Researchers of third year division B and the advising teacher are grateful for the collaboration of the educational community of the Secondary School Nº 241 of Pujato throughout the course of this project, especially the Head Teacher who considered the flexibility in time and space for executing the work by the students, so that they could take full advantage of the learning process proper to the research task they have developed.

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Furthermore, the translation work of this report by the Teacher of English Natalia Grosso is gratefully acknowledged.

To all of them, Thank you!

BADGES SELECTED

Students believe that their research could receive the following badges:

- **Collaboration:**

For the development of the research some members of the community where the school is located have collaborated. A technician from Pujato advised the students on the operation of the solar panel and on the use of measuring instruments. In addition, a former student of the school, who is GLOBE Alumni, collaborated in the definition of the site and in the application of the GLOBE protocols.

- **Community Impact:**

The research question arises from an issue that impacts the students when installing a solar panel in the school, since they believe that the cloudiness will reduce the transformation of solar energy into electricity. As the panel is installed in the front of the school and is visible to all who pass through there; the interest to know if the cloudiness influences the capture of solar energy impacts the community of Pujato that was interested in the research and in the results obtained.

- **Connection to a STEM Professional:**

Students organize a technical talk by a STEM professional, Technician: Alejandro Lambertucci who talks about different technical issues related to the solar panel installed in the school.

The students make a visit to the Institute of Physics of Rosario where STEM professionals, Systems Engineer: Federico Mateo and Meteorological Observer: José Pomar guide students and collaborate with the analysis of research data