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Portable Automatic Sensing System for Sustainable Precision Farm

J. Galvão[1,2], J. Fernandes[1], D. Pereira[1], M. Galvão[3], F. Neves[4]

[1] Department of Electrical Engineering, Polytechnic of Leiria, 2411-901 Leiria (Portugal)
Phone: +00351 244820300, e-mail: **jrgalvao@ipleiria.pt, 2192271@my.ipleiria.pt, 2191161@ipleiria.pt, mafaldasgalvao@gmail.com, fneves@ipleiria.p**
[2] R&D Unit, Institute for Systems Engineering and Computers /INESCCoimbra (Portugal)
[3] ISTécnico/Lisbon Technical University, 1049-001 Lisboa (Portugal)
[4] Department of Computer Science, Polytechnic of Leiria, 2411-901 Leiria (Portugal)

Abstract. Taking into account the world´s growing population and climate change, there is a need to decarbonize production processes and, in particular, intensive cultures carried out in greenhouses. There is a need to boost the energy and water efficiency of these cyber-physical systems, taking into account human consumption or floriculture, as well as European Community (EEC) and United Nations agreements and pledges, such as the European Green Deal (EGD) or the REPowerEU Plan [1,2] t is critical to develop systems that use integrated models to control these sorts of intense production, collect physical variable factors more efficiently, and achieve improved and zero greenhouse gas emissions (GHG). Finally, it is crucial for a digitalization in these intensive crops, in precision farm or greenhouses. The main objective of this work focuses on the conception of a portable automatic sensing system (PASS) for pH, electroconductivity and water flow, to control irrigation water quality in precision farm/greenhouses. The data collected by these sensors are made available in a mobile app for consultation by the operator. Another objective will be the local production of electrical and thermal energy from renewable sources (solar and biomass), hybrid systems and the use of cogeneration to supply energy to the greenhouse. A sustainable product policy also has the potential to reduce waste significantly.

Key words. Electrical Conductivity, Flow Meter, Automation, Sustainability, Precision Farm/Greenhouse.

1. Introduction

It is necessary to build a new narrative for a successful efficiency and carbon neutral in precision farm/greenhouses. The Green Deal is an integral part of this Commission's strategy to implement the United Nation's 2030 Agenda and the sustainable development and other priorities. As part of the Green Deal, the Commission will refocus to integrate the United Nations' sustainable development goals, to place sustainability and the well-being of citizens at the centre of economic policy, and the sustainable development goals at the heart of the European Union - EU's policymaking and action, (Fig. 1), [3,4,5].

With the goal of achieving carbon neutrality, the EU has already begun to modernize and alter its economy. It lowered greenhouse gas emissions by 23% between 1990 and 2018, while growing the economy by 61%.

Current policies, on the other hand, will only reduce GHG emissions by 60% by 2050. Much work remains, beginning with more aggressive climate action in the coming decade. For successful decarbonization and efficiency in greenhouses or precision farming, societies require an altogether new story.

In the popular narrative, the Green New Deal (GND) is the major aspirational pathway for achieving socially fair ecological sustainability. Its main point is that making a smooth transition away from climate-damaging fossil fuels is a very simple technological task.

On the other hand, the REPowerEU Plan, which was recently backed by financial and legal measures, is a new approach of developing energy sources. It is economical, secure, and supports sustainable energy for Europe to achieve new goals such as diversifying our energy suppliers, creating clean energy, and conserving energy, which is a feature to be improved in the model presented for the case study chosen for this research effort.

2. Main developments and features of the designed model

A1. Features of Precision Farm/Greenhouse

The precision farm/greenhouse under study are located in Cortes, near the city of Leiria - Portugal, with the following geographical coordinates: 39º42'36.7"N latitude and 8º47'16.2"W longitude and at an altitude of 67 meters. . It has a production area of 6,816 m^2. Relevant data for part of the model presented in figure 5. The greenhouse belongs to small company with more than 20 years of existence with family management.

The species produced in greenhouses: gerberas and carnations, require different needs for temperature and light and are mainly used in the ornamental market. However, trials are underway for some areas to start cultivating flowering species for human food and the "gourmet" food market, with trials of types of pest control that are not harmful to human health [6] (Fig. 2).

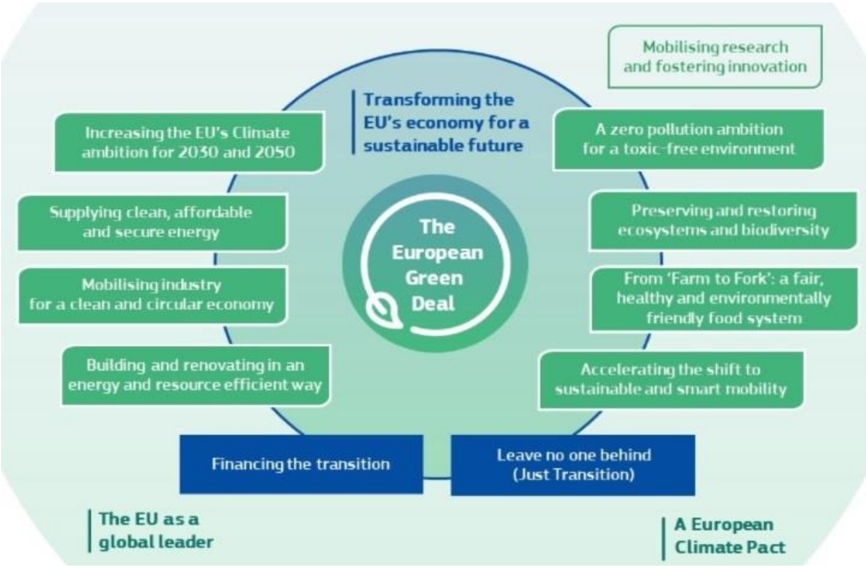

Fig. 1: European Green Deal focus on topic Farm to Fork.

Fig. 2. Main indoor view of greenhouse.

The gerbera planting area is made out of suspended beds that are set apart to make it easier for staff to move around the precision farm/ greenhouse. However, in the carnation flower, cloves are planted directly in the soil.

During the winter months, the interior heating is carried out by a hot air generator whose energy source is diesel fuel. It is located in the centre of the greenhouses and the heat distribution is carried out by air.

One of the parts of the proposed model will be the transformation to a renewable source, with biomass as the source of heat production.

Since there is a greater thermal amplitude between the interior and the exterior in the greenhouse at night, a thermographic analysis was performed to identify the locations with exaggerated heat losses and that require immediate intervention to mitigate these thermal losses, (Fig. 3).

After observing the thermographic image, it is concluded that due to the existence of a thermal blanket at the top, heat is retained uniformly (Fig. 4).

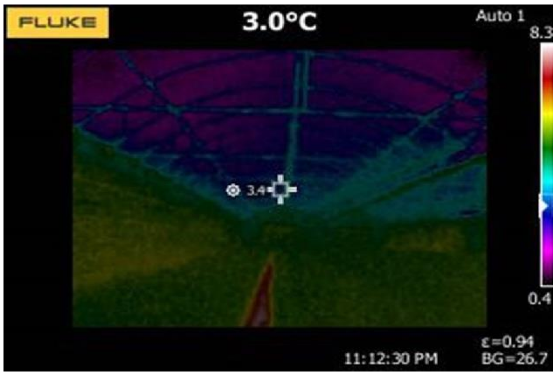

Fig. 3. Roof view, inside side without thermal blanket.

The same is not true on the side, where there is an evident temperature contrast, as there is no adequate insulation.

Fig. 4. Roof view, inside side with thermal blanket.

A2. Main Parts of Model Developed

Next, two main parts of the developed model are presented, taking into account other works previously developed in the area of energy and in greenhouses by some of the authors [7,8,9,10]:

i) One of them will be portable automatic sensing, which consists of a collection of sensors that gather physical variables and transmit the information to a digital support/cell phone. In order for managers to intervene quickly in the regulation of these factors; ii) the other component is local energy generation (Fig. 5).

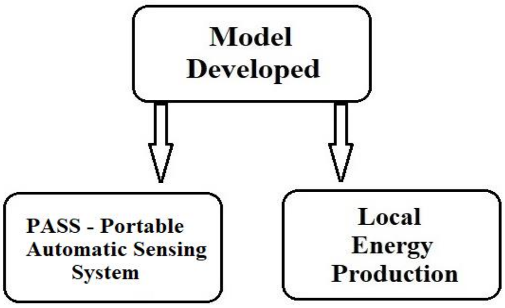

Fig. 5. Two mais parts of the Model Developed for greenhouse.

3. Characterization of PASS

The PASS - portable automatic sensing system calculates and controls the nutrients variables in the aqueous solution to feed the plants roots in multiple points of the precision farm/greenhouse (Fig. 6).

The pH sensor measures the concentration of Hydrogen ions, in moles of H^+ ion per liter of water-based solution, and rates them on a scale from 0 to 14, with 0 being the most acidic, 7 neutral and 14 the most basic, at a temperature of 25°C. The higher the concentration of Hydrogen ions, the more acidic the solution. The pH can be measured using a glass electrode, a pH meter or a pH indicator (colour change) [11].

The Electrical Conductivity (EC) sensor measures the ability of a material to conduct an electrical current over a certain distance, usually measured in Siemens or Ω^{-1} per meter, defined by the International System of Units (SI). Increasing the amount of aqueous solution: salts, chlorides, sulfides, carbonates and other ions present in a solution will cause a consequent increase in the EC of the aqueous solution (Fig. 7, 8).

The IoT development board for Arduino - ESP32 has Lora communication and will serve to receive the data provided by the sensors, process and send them to the gateway [12].

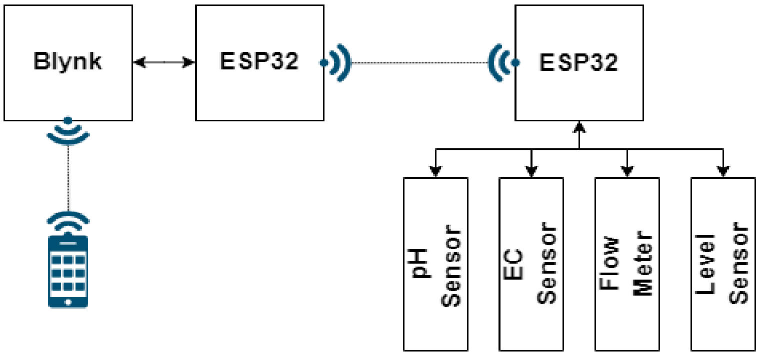

Fig. 6. Flowchart in developing for PASS - portable automatic sensing and remote control.

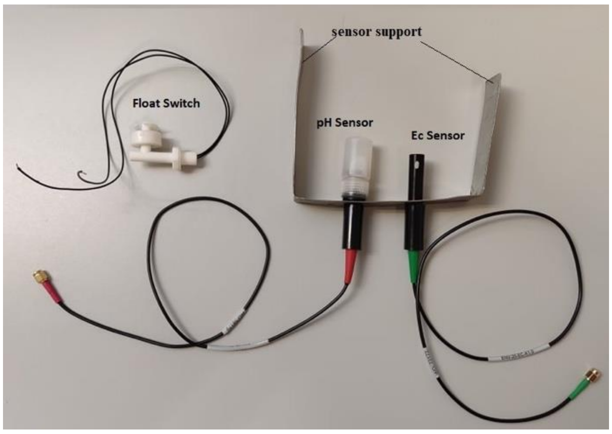

Fig. 7. Preliminary components of PASS: 2 sensors, 1 float switch and support.

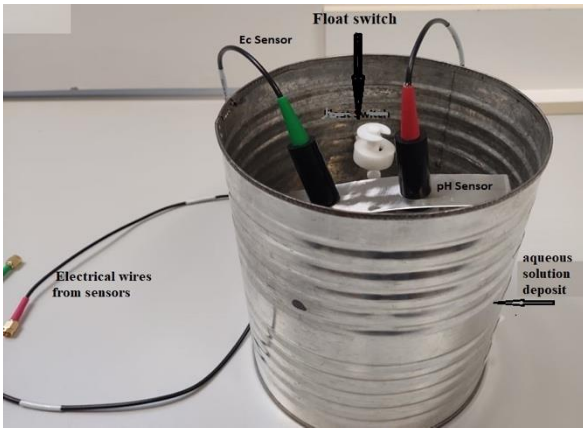

Fig. 8. 1st stage of assembly portable automatic sensing.

Blynk is a mobile application that allows the design of graphical interface and customize it according to what we want to control remotely, with multiple devices connected [13].

EC is commonly used in hydroponics, aquaculture and freshwater systems to monitor the amount of nutrients, salts or impurities present in the water. There are several types of level sensors to monitor the level of a liquid in a tank, for example float and ultrasonic sensors.

Thus, the different routines and programs designed provide that float type sensor will be used in this project. Float sensors are point level sensors, they are the simplest and least expensive, as they only indicate whether a substance is above or below a certain level. These monitor the liquid level in a tank using a float, magnet and reed switch. When the magnet present in the float approaches the reed switch due to the rise in the liquid level, this activates the reed switch, which in turn will perform a certain defined task [14].

There are several types of flow meters, including turbine type, electromagnetic type, ultrasonic type, each with its specific application. To carry out this project, a turbine-type flow meter will be used, due to its low cost.

The turbine type flowmeter translates the mechanical action of the turbine rotation due to the passage of fluid. When passing through the turbine blades, the fluid sets the rotor in motion. The turbine speed is proportional to the fluid speed, which allows obtaining a range of values in litre per minute [15].

As for the pH, EC and level sensors, sensors manufactured by Atlas Scientific will be used: The pH sensor chosen was the Mini Lab Grade pH Probe [16]. The EC sensor chosen was the Mini Conductivity Probe K 1.0 [17]. The level sensor chosen was the 90 Degree Float Switch [18]. The flow meter chosen was the Water Flow Sensor 1/2 - YF-B1 [19], from Botnroll, due to the measurement range being suitable for our project and the manufacturing material being better than the others that were made of plastic.

A3. Initial details of the PASS programming

A software that conducted these types of actions had to be constructed in order to accomplish the interaction of variables collecting and management. The implementation of the HardwareSerial.h> library has been activated in order to send/receive strings via serial communication:

```
#include <HardwareSerial.h>
```

Two ports (pHSerial and EcSerial) used for serial communication have been declared:

```
HardwareSerial pHSerial(2);
HardwareSerial EcSerial(1);
```

To carry out the serial communication between the ESP32 and the probes, 4 variables of type String and another 4 of type boolean were declared.
- The “input” variables of type String, store the Strings that ESP32 sends to the sensors.
- The “sensor” variables of type String, store the String that the sensors send to the ESP32.
- The “input” variables of boolean type, indicate whether the “input” Strings are complete.
- The “sensor” variables of boolean type, indicate whether the “sensor” Strings are complete. Float variables store the numerical value of pH and EC.
- The variable of type int, level indicates the port to which the float is connected.
- The boolean variable, flag_level, indicates whether the float was active.

```
String input_pH_string = "";
String sensor_pH_string = "";
String input_Ec_string = "";
String sensor_Ec_string = "";
boolean input_pH_string_complete = false;
boolean sensor_pH_string_complete = false;
boolean input_Ec_string_complete = false;
boolean sensor_Ec_string_complete = false;
float pH;
float Ec;
int var = 0;
int nivel = 18;
boolean flag_nivel = false;
```

This function (setup) is only executed once, at the beginning of the program to configure the baud rate of the serial communication, to 9600, as well as reserve, in memory, the spaces of each String and configure the float as an input.

```
void setup() {
  Serial.begin(9600);
  pHSerial.begin(9600);
  EcSerial.begin(9600);
  input_pH_string.reserve(10);
  sensor_pH_string.reserve(30);
  input_Ec_string.reserve(10);
  sensor_Ec_string.reserve(30);
  pinMode(nivel, INPUT);
}
```

The serialEvent functions are done at each program cycle. In this case they are used to receive.

```
void serialEvent2() {
  input_pH_string = pHSerial.readStringUntil(13);
  input_pH_string_complete = true;
}

void serialEvent() {
  input_Ec_string = EcSerial.readStringUntil(13);
  input_Ec_string_complete = true;
}
```

A4. Local Energy Production

TThis section of the model (shown in Figure 5) started with a comparison of existing software on the market that would meet the design criteria of a local power plant. It that would produce electricity using photovoltaic technology in the case study, we ultimately chose: PVsyst, see Table I.

The photovoltaic system simulation software use energy flow models, models that indicate how system components are interconnected. The first simulation software for the production of electricity by photovoltaic technology was originally from the United States.

There is currently a wide variety of design and simulation programs on the market that use different calculation methodologies. These programs are an asset, as they allow you to plan the system in the best possible way according to the user's needs.

To perform a simulation, it is important that the simulation is as accurate as possible and that it includes different possible scenarios.

As a summary, a comparison between programs is presented, which will perform the simulation of the local production of electric energy. In Table I a summary of its characteristics, abbreviations of design options and simulation typology, languages and databases [20, 21,22,23,24].

Table I - Analysis of software for local production of electricity

Name	Simulation typology	Language	Components database
Sunny Design	SAP, GCP , HPS	P	M, T, B, I, CC
SolTerm	TPS	P	IT
HomerPro	GCP	It,	B, W, IT, DG, BM, M
RETScreen Expert	SAP, GCP, HPS	It, F, P, G	IT
PVsyst	SAP, GCP, HPS	It, S	M, T, B, I, CC

Legend:
SFA/SAP: stand-alone photovoltaic system;
SFR/GCP:grid-connected photovoltaic system;
SFH/HPS: hybrid photovoltaic system;
STF/TPS: thermal and photovoltaic systems.
Main Languages: P: Portuguese, I: English, S: Spanish, G: German, F: French, It: Italian.

Component database:
IT: irradiance and temperature; B: batteries; W: wind generator; M: modules; BM: biomass; DG: diesel generator; I: inverter; CC: charge controller.

4. Next stages and Results

This study intends to improve energy and environmental efficiency, as well as a PASS platform that communicates the characteristics of physical variables to the process manager in real time so that the system may be managed to reduce water and energy consumption, which are everyday goals in this type of intensive crops production.

The PASS - portable automatic sensing system and as a demonstrator prototype needs to be tested in a real precision farm/greenhouse environment at various points of the production lines. There are specifics within the production line, with some differences in the nutrient supply. Liquid leftovers, which necessitate on-site testing to optimize the system, as well as regular cleaning and calibration of the sensors, to fulfill the needs of workers in nutrient and temperature control jobs for uniform flower growth.

An audit was conducted on the greenhouse complex, taking into account figure 5 and the area of local energy production, in order to understand the typology of electrical consumption in this case study and maximize energy efficiency. The goal was to obtain the consumption made during the sampling period, serving these for calculations of annual consumption, while also considering future expansion of the installations.

Based on the collected and predicted energy consumption, a photovoltaic system for self-consumption connected to the grid was designed, resulting in a proposal for the installation of 10 modules with a total peak power of 2.7 kWp, thus contributing to minimize electricity consumption [25].

Another aspect of the aforementioned energy audit was to develop a heating system, employing solid biomass as a renewable energy source, through a boiler for heating water, in order to understand the thermal part of this production technique [26].

For its sizing, the types of predominant cultures, the area and volume of space to be heated, the covering material of the greenhouses, as well as the history of temperatures for the place were considered. This resulted in a boiler with a nominal power of 1.200kW, and an underground deposit for storing the biomass, with a capacity of 26.2 tons.

4. Conclusion

This model is only completed after the tests that have already been configured in the development of an advanced area of production of this type of professional plant. In the cultivation area, the production lines (with pots or other systems) are of different types, so the use of the PASS will have portability for data collection at various points of the production lines. So certain tasks in this type of agricultural activity are improved with this equipment in the control of physical variables in precision farm/greenhouses.

All this is respecting the rules of an agricultural production in a sustainable context like:
- Construction and maintenance of a balanced agro-system without waste.
- Use of biological methods to control pests and diseases (by non-malignant insects).
- Exemption from agrochemicals, giving preference to products with low environmental risk.
- Low consumption of water and energy.
- Use of energy from renewable sources.
- Use of biodegradable materials.

Finally, it is intended that this work is a contribution to a greater awareness and motivation of the agents involved in this agro-industrial area, for an improvement in the use of energy sources inherent to this type of intensive production of plants, not only in the area of floriculture, but also in the food area (vegetables), as well as in the dissemination of the PASS model among associations and professionals in this area.

Acknowledgement

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References

[1] European Green Deal (EGD), Available: https://eur-lex.europa.eu/legal-content/EN/TXT/HTML /?uri=CELEX: 52019DC0640&from=ET
[2] REPowerEU Plan: affordable, secure and sustainable energy for Europe - European Commission, Available: https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/repowereu-affordable-secure-and-sustainable-energy-europe_en
[3] Larson, E.; Greig, C.; Jenkins, J.; Mayfield, E.; Pascale, A.; Zhang, C.; Drossman, J.; Williams, R.; Pacala, S.; Socolow, R.; et al. Net-Zero America: Potential Pathways, Infrastructure, and Impacts, Interim Report; Princeton University: Princeton, NJ, USA, 2020. [Google Scholar]
[4] Carlock, G.; Mangan, E. A Green New Deal: A Progressive Vision for Environmental Sustainability and Economic Stability. Available: https://www.dataforprogress.org/green-new-deal-report (accessed on 2 December 2021).
[5] Political Guidelines of President elect Ursula von der Leyen: Political guidelines for the next Commission (2019-2024) - ‘A Union that strives for more: My agenda for Europe’.
[6] NSW Government/Autralia, Department of Primary Industries, Types of greenhouses. Available: https://www.dpi.nsw.gov.au/agriculture/horticulture/greenhouse/structures-and-technology/types
[7] Oliveira, Filipe T; Leitão, Ségio A; Nabais, Adelino S; Ascenso, Rita M; Galvão, João R. Greenhouse with Sustainable Energy for IoT, In Technological Innovation for Cyber-Physical Systems - DoCEIS 2016 Conference Book, pages 416 - 424. ISBN: 978-3-319-31164-7; Springer International Publishing, 2016; doi: 10.1007/978-3-319-31165-4_39
[8] Adelino S. Nabais; João R. Galvão; Rita M. T. Ascenso; Sérgio A. Leitão, “Energetic System with Biomass and How to Mitigate Associated Problems”, 6th International Youth Conference on Energy/IEEE; Budapest, Hungary, (2017); doi: 10.1109/IYCE.2017.8003741
[9] Galvão, J., Nabais, A., Correia, H., Amaro, P., Negrão, A., Ribeiro, V., (2019), Intensive Agriculture Production in Low Consumption Energy Environment, Renewable Energy and Power Quality Journal (RE&PQJ), ISSN 2172-038X, No.17, pp. 354-359, july, doi: 10.24084/repqj17.310
[10] João Galvão, Rita Ascenso, Sofia Pereira, Licínio Moreira, Filipe Neves, “Smart Energy in Sustainable Services Building”, Proceedings of ICoWEFS 2021 Conference, editor Springer Nature Switzerland AG 2021, doi: 10.1007/978-3-030-75315-3_47
[11] “Atlas Scientific”, Available: https://atlas-scientific.com/probes/mini-ph-probe/
[12] ESP32 IoT development board for Arduino - Component Catalogue, Available: https://www.botnroll.com/pt/esp/3636-wemos-ttgo-esp32-sx1276-lora-868mhz-placa-desenvolvimento-iot-para-arduino.html
[13] Santos, P., Tese mestrado: Ciclo Energético, Eficiência e Sustentabilidade em Estufas; Mestrado em Engenharia Electrotécnica/ Santos. P., Master's Thesis: Energy Cycle, Efficiency and Sustainability in Greenhouses, Master's Thesis in Electrotechnical Engineer Polytechnic of Leiria, Portugal.
[14] “Atlas Scientific”, Available: https://atlas-scientific.com/probes/mini-e-c-probe-k-1-0/.
[15] “Atlas Scientific”, Available: https://atlas-scientific.com/float-switches/90-degree-float-switch
[16]“Botnroll”, Available: https://www.botnroll.com/ pt/biometricos/2541-sensor-caudal-de-gua-1-2-yf-b1.html
[17] “Flowmeters”, Available: https://www.flowmeters. com/technologies.
[18] “Sensorex”, Available: https://sensorex.com/ 2019/09/09/ph-sensors-need-to-know/.
[19] “SST Sensing”, Available: https://sstsensing.com/7-main-types-of-level-sensors/.
[20] Sunny Design WEB, “Nww Project/Novo Projeto, Sunny Design,” Available: https://www.sunnydesignweb.com /sdweb/#/Home
[21] Solterm 5.1 software: Available: https://solterm.software. informer.com/5.1/
[22] HOMER Pro software: Available: ttps://www.homerenergy. com/products/pro/index.html
[23] *RETScreen Exper*t Available: https://www.nrcan.gc.ca/ maps-tools-and-publications/tools/modelling-tools/ retscreen/7465
[24] PVsyst software – Irradiation data, wind an temperature in Cortes/Leiria, Available: https://www.pvsyst.com/
[25] E. Homa e R. Ramin, Optimal design for solar greenhouses based on climate conditions, Renewable Energy, vol. 145, pp. 1255-1265, 2020.
[26] C.Bibbiani, F. Fantozzi, C. Gargari, C. Campiotti, E. Schettinie G. Vox, Wood Biomass as Sustainable Energy for Greenhouses Heating in Italy, Agriculture and Agricultural Science Procedia 8, vol. 8, pp. 637-645, 2016.