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Sustainable Energies as an Educational Challenge: Regarding Engineering Studies at the University of Girona

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Abstract. Education is a keyword when environmental sustainability and climate change mitigation are pursued. It is a global objective that affect all the World, so social and technological universities are engaged with the aim of mitigating the change and improving the necessary adaptation. From the technical school of the University of Girona, our educational framework, consisting of a set of degrees with just some subject related with sustainable energies, is introduced. This work overpasses teaching activity within the university walls because contacts with local entities and the research of productive wind energy lands are also reported. Private and public contacts are both described, the problem is a social issue that focuses on the public interest but also a business opportunity for the private companies.

Key words

Environmental sustainability and climate change mitigation, sustainable energy sources, technological University framework, local entities synergies.

1. Introduction

Increasing fossil fuel prices, global warming and electricity demand will continue focusing on the efforts of our society. Sustainable energies are considered as clean sources of energy because their use can minimize the environmental impact and waste production and increase the social welfare based on current and future economic and social needs [1]. Sustainable energy sources offer an opportunity to reduce greenhouse gas (GHG) emissions and mitigate global warming through replacing fossil fuel based energy sources. Mitigation of climatic change is an important challenge that must be faced. The goal is to influence all the institutions, because a new way of thinking must be done. In this way, the United Nations objectives for this millennium include the environmental sustainability as one of their goals [2-3]. Paris Agreement sets the response to climate change as common actions developed by all the nations. It aims to keep the global temperature rise this century to well below 2 degrees Celsius above pre-industrial levels and as close as possible to 1.5 degrees [4].

Regarding education from a wide field of view, education on environmental sustainability cannot be limited to the STEM (science, technology, engineering, and math) disciplines. Climate adaptation must be extended to students of other fields so all population should have at least a basic understanding on this issue. In addition, proposals of specialized courses in many disciplines must be offered [5-7]. The American College & University Presidents' Climate Commitment have defined as imperative looking to education and training, research, community engagement and campus operations. Colleges and universities need to be centres of leadership on climate adaptation, not only in terms of conducting research but also in explaining its significance and steps necessary to deal with it effectively. Scientific and social research of higher education should make fundamental contributions in order to mitigate climate change and developing adaptation efforts by identifying the most pressing climate impacts [8]. These roles are relevant in the effort to prepare communities and make them more resilient in the face of growing climate change impacts [9-11].

Regarding sustainable energies as a global educational objective of the universities, our programs and curricula which are mainly oriented to engineering are presented. The importance of the educational institutions as the universities arises when the elaboration, implementation and, improvement through complementary processes are thought [12]. Education, research, operations, and community engagement activities are evaluated by colleges and universities with the objective of preparing future engineers according to the societal needs [8]. Complementary actions are developed by universities to cause relevant impacts to politics and society with the aim of improving the environmental sustainability. In this way, this research is focused on our university as an institution that not only educates students in order to perform their future jobs by considering the sustainable

energy sources. The work here developed includes educational activities but also embraces other actions that are done with the purpose of collaborating with other actors, as politics and society, in order to promote the use of sustainable sources of energy that changes the present behaviour of the society and achieves an environmental friendly sustainability.

This paper is structured as follows. Section 2 analyses the objectives and programs of our university referred to Engineering Education when sustainable energy sources are considered. Moreover, Section 2 describes the collaboration developed within our university by considering the educational activities as well as the mutual influences with our community when sustainable development is considered. Finally, Section 3 outlines the main conclusions of our work.

2. Our Role within the University of Girona

We are a group of professors that work at the Polytechnic School of the University of Girona, UdG, at Catalonia in Spain. All of us share the interest to teach and promote sustainable sources of energy. Our technical school is placed at the city of Girona that is located 99 km north of Barcelona and 55 km south of French border, see Fig. 1. Looking at the region, some possibilities of sustainable energy resources are PV and wind. PV energy is available at all the area. Solar radiation resource assessment can be computed for Girona area; Fig. 2 shows the estimated results with PV system of 1 kW [13].

Fig. 1. Location of Girona

Regarding wind power resources near coast areas, sea breezes and Garbi are thermal winds that blow side-onshore. Speeds of these winds are from 2.8 m/s to 11 m/s. Another existing wind is Tramuntana. It blows near French border in the northeast and close to the coast line. Tramuntana wind is strong with speeds of more than 11 m/s and can have wind gusts of more than 30 m/s. Other available local sources of sustainable energy are biomass and biogas that are present as a product of the forest or as a waste produced by farm animals. Once natural resources of our area have been mentioned, next subsections depict the actions that we have done during the last years. In this way, we have developed a set of different activities with the aim of teaching STEM studies at our school in the fields of electricity, electronics and mechanics, when sustainable energy sources are considered. Moreover, the tasks developed with local institutions are also commented as illustrations of how the climate change mitigation can be tackled from a wider consortium that includes private and public institutions

PVGIS estimates of solar electricity generation

Location: 41°57'47" North, 2°48'55" East, Elevation: 97 m a.s.l.,

Solar radiation database used: PVGIS-CMSAF

Nominal power of the PV system: 1.0 kW (crystalline silicon)
Estimated losses due to temperature and low irradiance: 10.0% (using local ambient temperature)
Estimated loss due to angular reflectance effects: 2.6%
Other losses (cables, inverter etc.): 14.0%
Combined PV system losses: 24.6%

Fixed system: inclination=35°, orientation=0°				
Month	E_d	E_m	H_d	H_m
Jan	2.98	92.4	3.73	116
Feb	3.74	105	4.71	132
Mar	4.40	136	5.70	177
Apr	4.27	128	5.66	170
May	4.51	140	6.07	188
Jun	4.76	143	6.55	196
Jul	4.73	147	6.60	205
Aug	4.58	142	6.38	198
Sep	4.27	128	5.81	174
Oct	3.73	116	4.95	153
Nov	3.05	91.4	3.90	117
Dec	2.78	86.3	3.49	108
Yearly average	**3.98**	**121**	**5.30**	**161**
Total for year		**1450**		**1930**

Fig. 2. Power estimated, yearly and monthly, with PV system of 1 kW at Girona area

A. Teaching Sustainable Energy Sources

Despite the fact that this section is mainly focused on STEM studies, the framework of our university includes other research actions that are briefly introduced at the beginning of this subsection [14]. Therefore, the research groups are classified according to their topics of research as social or technical/scientific. Social research groups are focused on the environment analysis and planning; the use of geographical information that can be used for preventing floods or drought periods, fluvial spaces development, landscape ecology and management of natural and agricultural spaces. When the technical/scientific research developed by groups is analysed, a diversity of topics split the research groups from different subjects as building construction when sustainability and technologies are considered as sustainable energy sources and fluid dynamics. In this context, the group of environmental physics focuses the research on: hydrodynamics and physical processes on natural aquatic systems, clouds, radiation at the atmosphere and climate, water quality and particle transport, climate change: evidences and physics processes. Regarding remarkable research institutions, ICRA, Catalan Institute for Water Research, performs a

set of activities related with the sustainable use of water resources. At the UdG level, the importance of ICRA is observed as a factor of revitalization that embraces all the university.

When teaching activities of master degrees are analysed, Management and Analysis of Climate Change is the only one that exists at our university. However, some master degrees have subjects that reflect the climate change and sustainably concepts. In this sense for instance, the interuniversity master degree of integrated crop protection is sensible to sustainability concept and it is aware of water resources.

In the remaining of this subsection, the efforts developed within the studies of engineering degree with the aim of teaching sustainable energy sources are presented. Our teaching areas embrace degree studies of engineering with specialities as mechanical, electrical and computer science. Each degree is developed during 4 years and corresponds to 240 ECTS, European Credit Transfer System. Consequently, a load of 60 ECTS credits is assigned to each year of study. According to the Bologna process, one ECTS credit approximately corresponds to 10 hours of on-site educational activities plus a workload of 15 hours of dedication of students [15]. These degrees provide engineers competent to deliver the concept and practice on different basics as electricity, electronics, control, mechanics and informatics while complementary subjects and other formation support play an important role because individual engineers can remain competent of sustainable development in their day-to-day work.
Regarding complementary subjects closely linked with sustainable energy sources, *installations of renewable energies* is the main one. It is noted that this subject belongs to the degree of Electrical Engineering but it is also offered to the students of Industrial Electronics and Automation Engineering that do the double degree study. The subject of *installations of renewable energies* includes basics of energy generation: solar PV, thermal energies, wind energy, biomass and geothermal energies. The theoretical contents of solar PV energies introduce: PV modules, batteries and accumulators, rectifiers and inverters, calculus of autonomous PV installations and coupled PV installations. Solar thermal and wind energy modules present the basics of theory and low power wind turbines. Finally, other sustainable energy sources as biomass and geothermal are briefly introduced.

Fig. 3 and Fig. 4 depict the mini-wind turbine placed at the roof of P2 building, and the PV placed at the roof of P1 building.

The laboratory of energies is linked to the subject of *installations of renewables energies*. In this way, the available material of the laboratory is used for developing the practices and is explained in the next paragraphs. It consists of 4 different modules:

Fig. 3. Mini-wind turbine placed at the roof of P2.

Fig. 4. PV cells placed at the roof of P1 labs

1) Module of solar PV energy. It involves a PV system with a degree of movement, a light panel with electronic power control for emulating the sun radiation, and a data acquisition system. Fig. 5 shows the module of solar PV energy.
2) Module of solar thermal energy. It has a solar thermal panel with a degree of movement, a light panel with electronic power control for emulating the sun heat radiation, a cooling system, which includes pipes and a tank, is used for storage of the thermal power, and a data monitoring system. Fig. 6 outlines the module of solar thermal energy.
3) Module of wind energy. It is formed by an open wind tunnel with a small-scale horizontal-axis wind turbine. The wind speed can be modified controlling the speed of AC, alternating current, motor of 18 kW fan and the load of the wind turbine can be regulated using a potentiometer.

Fig. 7 depicts the module of wind energy generation.

4) Module of geothermal energy. It is formed by 4 manholes with depths of 60 meters and diameters of 30 cm. Deep inside, a constant temperature of 17ºC is reached through all seasons. A system of pipes is used for cooling or warming the water used in the heating pump. Fig. 8 displays the module of geothermal energy.

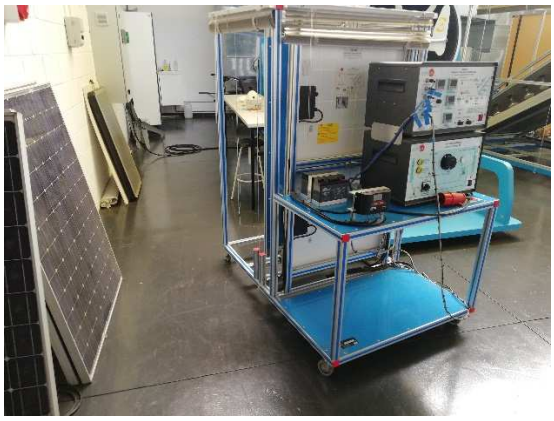

Fig. 5. The module of solar PV energy

Fig. 6. The module of solar thermal energy

Fig. 7. The module of wind energy

Fig. 8. The module of geothermal energy

From 2014 till 2018, 587 persons have visited the sustainable installations of our school. With the aim of promoting our university studies, the visits are addressed to high schools with the aim of motivating the students towards STEM studies and renewables sources of energy.

Other related subjects are: environment technologies, vehicles of electric power, and intelligent electric networks. Environmental technologies provide an introduction to the concepts of environment and sustainability. Students are taught on the following issues:

- Instruments for management of environment. Audits and cycle of life.
- Sources of energy and their environmental impact (measures and emissions management, efficiency).
- Solid waste (management and process). Applicable legislation. Processing the solid waste.
- Residual waters (management and process). Applicable legislation. Water purification.
- Gas emissions (management and process). Applicable legislation. Processes of purification.

B. Collaborations with Public and Private Institutions

The contact with Maria Crehuet, major of Ordis at 2014, has boosted the university collaboration beyond the municipality of Ordis. From the beginning, we realize that the lack of a wind map, which is suitable for mini-wind turbines, is an important inconvenient that must be solved. Without knowing the available wind resources, it is impossible to do a feasible business plan that considers the cost of the system and the generated power as an output deal. In order to solve the lack of information referred to Alt Empordà, we contact with DO Empordà and the net of meteorological stations.

DO Empordà is a local control board, in charge of ensuring that rules and regulations for production and

winemaking processes are implemented, guarantees the origin and quality of Empordà DO wines [16]. It also promotes technical research with a focus on improving the quality of winemaking. One research action developed by DO Empordà, with the collaboration of IRTA, Institute of Research on Agri-food Technology, and the section of plant health of the farming department of the Generalitat of Catalonia, and with support of Girona Provincial Council, was to fight mildew epidemic. A net of meteorological stations starts to run with the aim of improving the treatment for mildew. Synergies with our research group are evident because wind strength and direction are relevant data when wind harvesting potential is wanted to be studied. Since April of 2018, data from DO Empordà is being analysed in order to estimate the energy potential of the wind when Alt Empordà is sought.

Inferring the wind speed, for mini-wind turbines' use, can also be done by using the data obtained at automatic weather stations. Since 1996, a net of automatic weather stations, under management of the meteorological system of Catalonia, exists. Considering Alt Empordà as our research area, 11 automatic weather stations are found with a total of 6 that contain anemometer systems [17]. 5 of 6 have the anemometer system installed at 10 meters high from ground so data obtained is very relevant. The others are installed only two meters high, similar as in the case of DO Empordà. Despite the meteorological service of Catalonia publishes the data obtained at the automatic weather stations, to obtain a detailed information, from previous data, is one of our present objectives.

Our UdG group is multidisciplinary research team with expertise in different fields (electricity, electronics, mechanics and structures, fluids mechanics, smarts materials, control system technologies, vibration control, monitoring and fault detection, etc.). In the field of small wind energy generation and exploitation in urban and rural regions, UdG is the leader of CREOME RIS3CAT energy community in Catalonia that is formed by participants of universities, research institutes, public institutes, industrial companies, civil societies and end-user (farms) [18]. Belonging to RIS3CAT energy community is an opportunity to contact with other research groups and industrial companies interested on developing research within the field of sustainable energies. From our relationships with ICMAB and Solarworkcat, other fields of research as energy storage started. Energy storage attracted us to the development of ACAES, Adiabatic Compressed Air Energy System, for thermal and electrical energy storage for residential and non-residential users [19]. The objectives are to reduce energy costs and increase the reliability of energy supply from renewable sources. ACAES allows to store the electricity generated from renewable and conventional sources to pressure energy. Further thermal energy can be recovered from conversion process, stored and used for space heating or hot water. ACAES allows to reduce peak energy demand by utilities (peak shaving), decrease the size of the power generation devices, reduce the power of the contract with the grid operator, size the system on the load curve power users in order to increase energy efficiency and economic sustainability reducing management costs with the advantage to reduce operating costs, use of non-toxic materials. Our consortium that include research entities as ICMAB and UdG, and private companies as Solarworkcat and Fleximecan, is actively working for developing a micro-ACAES. Due to the commercial interest and business, the research developed is confidential.

It is also remarkable the research developed by colleagues from our school about smart grids, (intelligent electricity distribution grid), that improve the efficiency and the hosting capacity of distribution networks [20]. It is considered a highly distributed renewable generation by introducing flexibility and control in the low voltage grid. Continuous power flow control between storage and the grid can be achieved with advanced power electronics devices that allow storage management capabilities providing both switching and energy balancing capacities. Low voltage grid monitoring combined with the capability of actuating on the grid will benefit from robust scheduling methods to support self-healing and grid reconfiguration. This will allow efficient grid operation and a maximised renewable hosting capacity. The link between research and education once more becomes clear when the subject of "intelligent electric networks" is thought.

Finally, despite that the degree of computer science does not include specific subjects related to sustainable energy sources or climate change and sustainable development, students and graduates are able to develop multiple applications related with environment protection. In collaboration with Nicolas Boccard professor of the Economics Faculty, students of computer science have developed an application for air quality detection [21]. Fig. 9 shows the necessary hardware and software for particle detection.

Fig. 9. Hardware and software for particle detection

3. Conclusion

Sustainable energies and climate change mitigation are important educational issues that universities should include in their curricula because are based on economics and social needs. From experiences from our university, we conclude that it is not necessary a specific technical formation when sustainable energy sources are analysed. In this way, students of degrees such as: electrical engineering, industrial electronics and automation engineering, and mechanical engineering, are able of developing research related with sustainable energy sources despite their curricula contain few specific subjects linked with the sustainability topic. Technological formation of other degree studies, as computer science, are also able to work with sustainable energy sources and climate change mitigation without any specific formation subject.

Synergies between universities and external entities are also developed. The contact with Ordis council is an example that allow us to extend the research to be developed outside of the university walls. Students can improve their competences by developing solutions for real world problems. Ordis council agreement permit us a technological collaboration where the need of a wind map suitable for mini-wind aero generators is pointed out. Collaboration is not constrained to public institutions, belonging to RIS3CAT energy community is an opportunity to contact with other research groups and industrial companies interested on developing research within the field of sustainable energies. From our relationships with ICMAB and Solarworkcat, other fields of research as energy storage started.

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We thank the collaboration with Maria Crehuet that was major of Ordis when we sign the agreement at 2014. She has made important efforts to promote the use of sustainable sources of energy and to meet the real needs of local territory. Ivan Garcia is owner of Solarworkcat, he impulses innovation and collaboration between private and public institutions. Xavier Granados, member of ICMAB, has proposed a new energy storage system to be developed and evaluated. Finally, Nicolas Boccard is a professor of the Economics Faculty of UdG, he is interested on inferring the quality of air, he impulses the development of applications with informatics students.

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