Impactful engineering education through sustainable energy collaborations with public and private entities

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Abstract

Purpose – This paper aims to report on a case study concerning the development of sustainable energy partnerships involving engineering faculty and undergraduate students at the University of Girona, Catalonia, Spain.

Design/methodology/approach – Faculty were motivated to seek partnerships with public and private entities in the local area for the purposes of realising mutually beneficial outcomes. The educational programmes of future engineers, when sustainability is considered, are analysed. Education for sustainable development has to include multidisciplinary active learning as a desirable competence. Active learning can be obtained when problems are based on real life because they are most motivating for students. Constructive alignment component is obtained because learning objectives are linked with learning activities related to the needs of public and private entities.

Findings – Through the provision of technical expertise, the adoption and success of renewable energy projects was facilitated on the one hand, while final year undergraduate students benefited in terms of hands-on experience in helping to bring these projects to life, drawing on the knowledge and skills they had acquired throughout their degree programmes. These works are addressed to students by faculty members with the aim of developing and promoting renewable energies. Outcomes from partnerships surpassed expectations; not only were different benefits realised as were initially hoped for, but this success led to partnerships being sustained over time.

Originality/value – Fossil fuel-based energy systems are associated with a myriad of negative environmental and social externalities. It is difficult to overstate the importance of transitioning towards alternative low carbon energy sources for climate change mitigation which are less centralised compared to the status-quo for energy security and energy independence. By actively facilitating the development of decentralised renewable energy sources in Catalonia, the projects reported herein are of significant value in social environmental and educational terms.

Keywords Sustainability, Higher education, Collaboration, Spain, Climate change, Energy, Partnerships, Catalonia, Wind power, Renewables, Engineering curricula

Paper type Case study

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Introduction

Increasing fossil fuel prices, climate change and electricity demand will continue to be important societal concerns in the years and decades to come. Sustainable energies are sources of energy consumed at insignificant rates in comparison with their supply. On the other hand, clean energy is any form of energy obtained with environmental harmless and non-polluting methods. Sustainable clean energies have the potential to minimise environmental impacts, including waste production, and increase social welfare based on current and future needs (Panwar *et al.*, 2011). Sustainable clean energy sources offer an opportunity to reduce greenhouse gas (GHG) emissions and thus mitigate climate change through replacing fossil fuel-based energy sources.

It is difficult to overstate the importance of climate change mitigation based on the consensus understanding of the scientific community regarding actual and foreseeable climate change impacts. People, animals, and plants in tropical areas, small islands, mountains and Arctic regions are particularly vulnerable to deleterious climate change impacts (McIver *et al.*, 2015; Pacifici *et al.*, 2015). Direct impacts due to intense and frequent changes in temperature and precipitation are expected (heat, drought, storms, floods and fires). Related effects consist of decreasing crop quality, food availability, and lack of drinking water. Due to all these negative effects, climate change compromises human health and well-being in physical and psychological terms (Luber and Prudent, 2009).

To meet the climate challenge, the goal is to influence institutions at different spatial scales, because a new way of thinking must be diffused and implanted across all areas of decision making. In this way, many of the 17 Sustainable Development Goals (SDGs) of the 2030 Agenda adopted by the General Assembly of the United Nations include environmental sustainability issues: Affordable and Clean Energy (Goal 7); Sustainable Cities and Communities (Goal 11); Responsible Consumption and Production (Goal 12); Climate Action (Goal 13) (United Nations, 2017).

Related to climate, the Paris Agreement viewed the response to climate change in terms of common actions developed by all nations, with the overall objective of keeping global temperature rise this century to well below 2 degrees Celsius above pre-industrial levels and as close as possible to 1.5 degrees (United Nations, 2016). The recent Intergovernmental Panel on Climate Change (IPCC) report includes an analysis of the mitigation pathways in a sustainable development context. It points out that mitigation policies may have positive or negative impacts on the achievement of other societal objectives, such as sustainable development (IPCC, 2018). Adaptation and mitigation is challenging and it requires trade-offs with and among the SDGs. Nevertheless, the IPCC report considers with a very high confidence that making sustainable development a priority becomes consistent with efforts to adapt to climate change (IPCC, 2018).

Education for Sustainability (EfS) has the purpose of preparing the students with the skills, knowledge and habits of mind to participate in the development of a sustainable and prosper future (Cloud, 2014). The Education for Environmental Sustainability (EfEs) goes a step further in the sense that it recognises the complexity of the environmental problems and educates the students into the critical thinking and taking actions to improve the environment. Several universities have developed short-term courses to provide certificates in Education for Environmental Sustainability available to all disciplines (University of Cincinnaty, 2019; University of Texas at Austin, 2019).

Education for Environmental Sustainability cannot be limited to the STEM (science, technology, engineering, and mathematics) disciplines. Climate knowledge and climate consciousness must be extended to students in other fields so that a sizeable proportion of the population has at least a basic understanding of this issue. Proposals for specialised

courses in many disciplines must be offered. The American College and University Presidents' Climate Commitment, launched in 2006, underscores the imperative of education and training, research, community engagement, and campus operations in this domain. Colleges and universities need to be centres of leadership on climate mitigation and adaptation, not only in terms of conducting research but also by explaining the significance of that work, the research questions it has sought to address, and the steps necessary to ensure socially desirable outcomes. Research in higher education (spanning not just sciences and economics but also arts, humanities, and social sciences) should make fundamental contributions to mitigating climate change and developing adaptation efforts by identifying the most pressing climate impacts. Politics should factor climate change into a broad array of decision domains, involving researchers and other salient stakeholders from a diverse array of disciplines and interest groups. Universities also have an important role to play in terms of community engagement, to prepare people and make them more resilient in the face of growing climate change impacts (Prokopy *et al.*, 2015; Stephens *et al.*, 2008).

Results from case studies in learning and education for sustainability carried out in seven countries conclude that universities should integrate practice and theory, requiring the development of collaborative approaches (Leal Filho *et al.*, 2018), should encourage the integration into more courses making clear the connections between several areas of knowledge (Hanning *et al.*, 2012). Furthermore, this education on sustainability should meet the needs of industry with competences that students often claim not to possess at the end of their undergraduate engineering degrees (Hanning *et al.*, 2012). A recent case study shows that very short modules (one or two days long) may lead to significant changes in the student perception of sustainable designs leading to significant learning increases (McWhirter and Shealy, 2018).

Regarding sustainable energies as an educational objective of universities, the aim of the paper is to present details of successful sustainability partnerships which not only imbued undergraduate engineering degrees with practical experience but also yielded important environmental and social benefits beyond the campus.

The remainder of the paper is structured as follows. The next section introduces the climate change challenge and the role of universities before the focus moves to specifically considering the role of engineering education. Details of specific collaborations for sustainable energy, between public and private entities and universities are then provided. Finally, conclusions are drawn based on these experiences.

The climate change challenge and the role of universities

The role of universities to climate action includes understanding of climate change and how mitigation actions can be done. Leadership of universities regarding research and educational programmes is essential. However, adaptation and planning should be encouraged by politics by developing laws and actions that allow engagement of society. Rigidity of institutional structures, lack of facilities and resources and perception or lack of empowerment to make changes can be important barriers that should be overpassed. The institutions that govern natural resources and public goods are a deep driver of barriers and limits to adaptation (Barnett *et al.*, 2015). Academic institutions are suggested for overcoming hindering factors as risk management and sustainability planning processes by developing adequate professionals (Iyer-Raniga and Andamon, 2016). The higher education sector can act as a leader in building institutional resilience at the local scale (Kautto *et al.*, 2018). The importance of climate change has influenced the educational activities of universities, not only with respect to STEM studies. Climate change and sustainable

development require buy-in and input from different institutions that embrace diverse topics within different degrees including economics, law, agriculture, politics and health.

Economics education, for example, has to consider the capacity to adapt to and mitigate climate change. Identification of accurate models which can predict salient climate change phenomena can help optimise mitigation and adaptation responses. Universities' educational activities seek to develop the necessary skills for matching economic development with the protection of natural resources. By definition, such undertakings should be inter-, multi- and trans-disciplinary endeavours where ethics, sustainability, and social justice are considered. Indeed, many universities offer bespoke programmes at the interface between economics and the environment; these tend to be at the postgraduate level although the UK¨s University of York offers a 3 year undergraduate degree in Environment, Economics and Ecology and has been at the forefront of education and research in environmental economics since 1992 (University of York, 2019).

The relationship between law and climate change mitigation is also very important. Legislatures, administrative agencies, courts, and regulators are tasked with ensuring GHG reduction commitments are met without compromising human rights, and economic development goals. The lawyers of the future will be increasingly confronted with the choice between defending the interests of private companies or the world as a whole. Moreover, controversial tensions between those nations responsible for climate change and those that disproportionately suffer the consequences of climate change can be expected to increase in the near-term (Busby *et al.*, 2018; Schipper and Pelling, 2006). Thus, the role of universities, when the objective of teaching law is considered, becomes essential and there are many centres of excellence in environmental and energy law around the world including at the universities of Vermont (University of Vermont, 2019), Melbourne (University of Melbourne, 2019), and Utrecht (Utrecht University, 2019).

As the final example here, agriculture is considered. Sustaining the production of crops and animals under climate change will require a wide range of adjustments related to farming practices. Adaptive solutions are numerous and may include the timing of farm operations, technical solutions that protect orchards from damage due to hailstorms, improving ventilation of animal shelters, and the selection of crops and varieties better adapted and more resistant to changing temperatures and humidity levels. Some countries, as in the case of the European Union (EU), have a budget that supports actions to adopt and maintain farming practices that help meet environment and climate goals. The EU has also been a significant funder of large-scale collaborative projects focused on the agriculture-environment nexus involving many institutions of higher education in different Member States.

Engineering education and sustainability

Overview and programmes

Engineering education has a key role to play in helping to meet the challenges associated with prosperity and sustainability around the world. These challenges are dynamic and as such engineering curricula have to be adapted to the times and social needs. Hence, the universities need to be more proactive and aggressively infuse ethical and moral teaching and values into their curricula (Al-Rawahy, 2013).

The design and incorporation of sustainability issues into engineering curricula at the university level has attracted the interest of researchers (Abdul-Wahab *et al.*, 2003; Byrne *et al.*, 2013; Lavey, 2018; Lund *et al.*, 2017). According to the work developed therein, and the opinion of students and faculty, a generalist undergraduate degree in engineering is deemed desirable for those who subsequently wish to specialise in the energy and environment

domain. However, specific studies are preferred at the postgraduate level. Discussions about the relative merits of generalist versus specific undergraduate degrees in engineering remain open and vibrant. These types of discussions are played out in certain higher education institutions where different undergraduate engineering degree programmes are offered that include conventional engineering and specific sustainability curricula (McPherson and Karney, 2015). Within this context, attempts to add one or two units of study on renewables to conventional engineering degrees may produce graduates with insufficient knowledge or understanding to use renewables effectively, unless they go on to pursue more specialised postgraduate programmes. On the other hand, the amount of foundational engineering theories, topics, methods and coursework that are necessary to do justice to the field may limit the potential of undergraduate programmes to offer multi- and inter-disciplinary courses with a substantive focus on sustainable energy systems.

The underlaying methodology of this case

Partnership with local entities is a helpful tool when students learning is searched for. These collaborations can be used to explore different perspectives than the obtained within the walls of universities; such as social needs or environment resources under stakeholder point of view. In this context, examples of actual practice and demonstrations of where progress towards sustainability is and can be made in the real world, are educational objectives (Fenner *et al.*, 2005). Constructive alignment (CA) is proposed because students construct meaning through relevant learning activities and teachers set up a learning environment that supports the learning activities appropriate for achieving the desired learning outcomes (Biggs, 2003).

The methodology outlined increases the student's competences by approaching students to real problems related with sustainable energy sources. In this way, the knowledge can be developed through living cases that can be used to connect and engage learners with contents (Grassberger and Wilder, 2015). Active learning is an important objective of the pedagogical methodology that can be done in cooperation with external parties. In this way, to recognise that these problems are not perceived in the same way by various stakeholders around our planet is considered an important goal for the educational process (Mulder *et al.*, 2012). Partnership with local entities is a well-known educational methodology that can be developed through PBL (project-based learning) or forming a community partnership to enhance education in sustainability (Guerra, 2017; Allen-Gil *et al.*, 2005).

In the present case study, the contact with public and private local institutions allows outcomes through applications which are strongly related to social needs. Within this context, "energy is increasingly understood as a comprehensive and tailor-made service solution for communities and individual households" and "the aim to narrow the research gap linked to foresight in services, by examining services in the area of sustainable energy systems, is one of the main challenges of today" (Hyytinen and Toivonen, 2015).

Local networking is an important tool that has allowed the contact and collaboration between the university and the public and private entities. Objective alignment and networking are making that the number of entities involved are growing up because collaboration and mutual benefits are connected.

Engineers, education and sustainability at the University of Girona

Laying the foundations in the classroom and laboratory

The University of Girona is a public multidisciplinary institution in Catalonia, Spain, that offers programmes of study at different levels (undergraduate degrees, master's and doctoral) (Universitat de Girona, 2019). Several faculties/schools form the University according to the Spanish Law of higher education (BOE, 2001). The Polytechnic School of

the University of Girona has faculty members of different disciplines that share an interest in teaching and promoting sustainable sources of energy.

In what follows the efforts developed within undergraduate engineering curricula are focused on teaching students about salient theories and methods which are pertinent to energy and the environment and preparing them for postgraduate studies and careers in this field. Four undergraduate engineering programmes offered by the University of Girona are analysed: Electrical Engineering; Industrial Electronics and Automation Engineering; Mechanical Engineering; Computer Science. Each degree is a four-year programme 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 corresponds to approximately 10 h of on-site educational activities plus 15 h of self-directed study by students (European Commission, 2018).

In accordance with internationally recognised best-practice guidelines, these degrees result in students becoming engineers who are theoretically and practically competent to carry out jobs or pursue postgraduate research focused on electricity, electronics, control, mechanics, and informatics.

In the third year, students on the Electrical Engineering, Industrial Electronics and Automation Engineering and Mechanical Engineering programmes take three-credit course entitled *Environmental Technologies*. The contents of this subject deal with environmental impact and management, including waste processing and purification of water and emissions. Renewable energy generation is not considered within this subject.

Also in the third year, the students on the Electrical Engineering programme take a four-credit compulsory course entitled *Renewable Energies*. By contrast, currently on the Computer Science programme, there are not bespoke courses which focus specifically on environmental and energy issues. Table I shows the undergraduates studies analysed and the number of ECTS credits available for the different studies.

The contents of the course of *Renewable Energies* include the basics of energy generation, solar PV, thermal energies, wind energy, biomass and geothermal energies. The theoretical content of the course is complemented with a set of practices:

- Solar PV practices include the determination of basic parameters in PV panels, the relation between radiated and generated energy, maximum performance of panels, influence of temperature, features of serial and parallel coupled panels, performance of PV systems;
- PVsyst software is used for running simulations of PV systems to estimate production;
- Solar thermal energy practices cover thermosiphon performance, flow and temperature relationships, studies of solar collectors and tilt angle, thermal isolation of pipe systems;

Table I. Sustainability offered credits and undergraduate studies

Undergraduate studies	Compulsory subjects Related with sustainability	Business practices	Final degree project
Electrical Engineering	3 + 4 credits	15	15
Industrial Electronics and Automation Engineering	3 credits	15	15
Mechanical Engineering	3 credits	15	15
Computer Science	0 credits	15	15

- Wind energy practices with mini-wind turbines introduce the estimation of power energy extracted from wind by applying Betz's law. Laboratory practices study load variability effects under different wind types; and
- The final practices consist of visits to actual renewable energy installations on campus, specifically, the geothermal installation in the laboratory of energies, the mini-wind turbine installation and PV cells on campus buildings. The PV cells are BP 4160S monocrystalline modules and, in total, 96 modules (160 W each) cover 120.96 square metres of surface with a peak power of 15.36 kW (module orientation is 0°, with a horizontal slope of 20°). The wind turbine is an ENAIR model with a maximum power of 2.2 kW at 10m/s wind. The system includes: a charge regulator for stationary batteries, a set of 12 batteries (for an overall 24 V DC system), and a 230V monophasic inverter. For wind speeds higher than 10 m/s, a mechanical and electric brake system reduces turning velocity of the blades. Both the PV and wind energy installations have monitoring systems for performance evaluation.

Since 2014, 587 people have visited these installations on our campus (98 per cent were students from secondary schools and 2 per cent students of employee training courses). With the aim of promoting our university, visits from high school students are encouraged with the aim of motivating them to pursue STEM studies.

Learning outcomes from student's point of view are recorded through opinion poll at the end of their studies. From interviews of the last five years, two remarks are outlined:

(1) To the question of which three subjects have given you less learning (in proportion to their credits), students rate the three-credit compulsory course *Environmental Technologies* within the last quartile. At the same time, to the question of which three subjects have devoted you less time (in proportion to their credits), the very same subject is also rated within the last quartile.

(2) Suggestions of students, when the degree is analysed, are favourable to more practical contents and less theory in their curricula.

The last point was also remarked by the outcomes of the massive opinion poll launched in 2017 to the people who graduated at the Catalan universities in the year 2013. At the moment of the poll, the former students of the undergraduate industrial engineering programmes here analysed had a 92 per cent employment rate. These people provided a mark of 4.9 over 10 in the question of usefulness of the practical training at the University (AQU, 2017). Thus, actions to improve the practical skills of the students are needed, as in the case study here described.

Beyond bespoke courses with a specific focus on energy and environment issues, many, if not all, other courses on our undergraduate engineering programmes are necessary precursors for energy and environmental engineering. Viewed in this way, the design of curricula, follows the logic of Lund *et al.* (2017) discussed above who emphasised the benefits of generalist undergraduate degrees.

Finally, and most importantly from the perspective of this case study, a compulsory component of all four of our undergraduate engineering programmes is a large (15 credits) final degree project that is obligatory for all the students. Relatedly, students on all four programmes can select to take the optional *Business Practices* course (again, this is substantive, totalling 15 credits). This final project, and the optional practices course, gives students the opportunity to apply and further develop their knowledge in the world of sustainable energy resources. These final elements are strongly influenced by external activities beyond the university walls which have yielded mutual benefits for all involved.

Partnership between university and private and public institutions has boosted a set of profits for all the memberships. University students can improve active learning methods by understanding, and developing applied solutions to real problems while university professors increase the knowledge of the local needs through collaboration with the local institutions. Both public and private institutions receive the university help and support to develop sustainable energy sources. Technical support is highly appreciated; actions for measuring the local wind resources, developing new wind generators, or improving the existing ones are carried out. A network that includes all memberships is actively running.

Collaborations with public entities

This subsection explains and explores research developed between our group of professors, the municipality government, and an exemplar farm in the locality. As noted above, there is a wind turbine on campus, but it is for educational purposes only; wind conditions in Girona city are not adequate for wind harvesting. While this is an important reminder for students of the constraints imposed by intermittency it is also problematic both from the perspective of imbuing students with a passion for renewable energy sources and for teaching them about certain operational aspects of wind turbines. Accordingly, it sought to identify an area with high wind potential and opened a channel of communication with the Ordis municipality in Girona in an attempt to meet this objective. This was a pertinent choice given the inception of *Ordis Sustainable*, an initiative to promote the use of sustainable energies in the area (Ordis Sostenible, 2018).

Further, Ordis belongs to the Association of Micro-villages in Catalonia (AMC). The AMC is a non-profit entity that aims to give a voice to villages with less than 500 inhabitants. It represents the interests of more than 320 villages; collectively these villages occupy near 50 per cent of the Catalonian land area but with low demographic impact (AMC, 2018).

Looking to aesthetics and tourism, the AMC promotes mini-wind energy generation but it is not in favour of large wind generators because of their high visual impact. Clearly there are important and interesting subjectivities enshrined in this position *vis-à-vis* whether, where, and why wind installations enhance or detract from landscape quality. Within this context, governmental decision makers in the Ordis municipality are leading promoters of sustainable sources of energy. Following our initial contact with Ordis, two collaboration agreements were subsequently signed in 2014. One was public with the Ordis Council with the aim of promoting sustainable energies. From the Ordis side this was championed by the mayor, Maria Crehuet, and it was essentially a technological collaboration between the University of Girona and the Ordis Council concerning the management, promotion, and study of wind installations (University of Girona, 2014a). The second collaboration agreement involved a private entity, the Vilà farm, with the objective of promoting sustainable energy sources and installing a mini-wind turbine (University of Girona, 2014b).

The agreement with the Ordis Council focused on the use of mini-wind turbines and assessing the wind energy potential of the municipality. In terms of the latter, anemometers were installed to gauge wind potential and analyse power production versus wind velocities. Other aspects of interest in this collaboration include the design of an automated system to safely stop the generator when wind speed is greater than a predetermined threshold value, integration of power production and anemometer information, and dissemination of results to a primary school in the municipality for the purpose of developing activities and specific monitoring systems. To this end, a number of fourth year undergraduate engineering students completed their final projects to answer salient research questions emanating from this collaboration. For instance, undergraduate students built low cost anemometers using two different methods by means of cups [Figure 1(a)] and ultrasonic sensors [Figure 1(b)].

A cup anemometer can be considered as a mechanical system where the speed of rotation is proportional to the wind speed, while ultrasonic anemometers are electronic systems that measure ultrasonic waves to quantify wind speed and direction.

Developing practical solutions such as these reinforces the knowledge acquired through multiple courses on the engineering programmes. In the case presented, analogue electronics, power electronics, digital electronics, programmable devices, electronic instrumentation, communications, industrial informatics, industrial applications of microcontrollers and electronic project development are the necessary subjects followed by students throughout their time at university which collectively enabled them to design and develop these anemometers.

Students' learning is accomplished by developing projects related with sustainable energy sources. It is not pursued to develop competitive solutions versus commercial ones. The objectives are to help the local community in its development and to integrate different knowledge by developing real projects. At the student level, the objective is to develop a whole engineering project that improves his/her practical skills within the sustainable and clean energy topic.

The Ordis Council point of view is favourable to the collaboration with the university since the university has sound opinions and it gives support to develop and to promote the local use of sustainable energy resources. Networking between the entities and the University is seen as a positive tool because it allows contacting with new institutions that are aligned with the sustainability objectives. Universities can play an important role when networking is analysed, especially when the contact with research institutions is searched. In this way, the agreement between the village and the university is maintained along the time.

Collaborations with private entities

The collaboration with Vilà farm was focused on the installation of a mini-wind turbine, started close in time as it was with Ordis Council. It was the major of Ordis who mentioned

(a) **(b)**

Figure 1.
(a) Cup anemometer *in situ* designed by a fourth-year undergraduate engineering student at the University of Girona; (b) ultrasonic anemometer *ex situ* designed by a fourth-year undergraduate engineering student at the University of Girona

the Vilà farm as a private entity suitable for starting new collaborations. Vilà farm is located on a hill and it is an excellent place for installing and operating a mini-wind turbine. It is a traditional farm which strives for sustainability and endeavours to contribute positively to the locality through environmental education. Indeed, beyond the mini-wind turbine which is the cornerstone of our collaboration, the farm also makes use of PV cells for solar power and effectively captures and reuses rain water in its operations. In sum, the Vilà farm is an admirable example of an autonomous and environmentally benign system.

The collaboration between the farm and the University of Girona started with the selection of technical material (a mini-wind turbine together with AC/DC converters, DC/AC converters, etc). Once the location for installing the mini-wind turbine was selected, Joaquim Vilà (owner of the farm) built the necessary infrastructure for the mini-wind turbine. The power obtained is used to drive a water pump that provides service to animal shelters on the farm. Figure 2(a) shows the mini-wind turbine being installed at the farm. This collaboration between Vilà farm and the University of Girona again generated mutual benefits because students learnt how to develop practical solutions for the farm. Again, a wealth of different courses previously completed by the students provided the necessary precursors for accomplishing the technical objectives at Vilà farm. Interestingly and importantly, our collaboration with the farm did not end with installation of the mini-wind turbine. Collaboration continues to focus on teaching sustainable energy sources and due to strong winds in this area, it transpired that there was a need to develop bespoke blades that were robust to the particularities of the on-site meteorological conditions. This clearly increases the range of technical skills that need to be drawn upon to accomplish this task whilst also providing an important reminder to students of the potential limits to unleashing economies of scale in this sector.

Collaboration with Vilà farm and the university includes also dissemination aspects (Ordis sostenible, 2018). Since 2017, Vilà Ecofarm starts to exist as a new private entity with the aim to explore new projects by joining tradition and innovation. Rural world offers a great potential of applicability when sustainable energy sources are considered; see Figure 2(b). Vilà Ecofarm wants to participate in the dissemination of sustainable energies in three different areas: social, environmental, and educational. Collaboration with university is sought by Vilà Ecofarm as a capstone of their dissemination project because the support of the university is considered as a strategic alliance.

Private partnership is not constrained to Vilà farm. Olive oil and wine are traditional products that agriculture offers in this Mediterranean area. Quality wines and healthy plants are objectives of associated designation of origin (DO) producers of the region (DO Empordà, 2018). Synergies with the University of Girona arise because they collect on-field

(a) (b)

Figure 2.
(a) Installation of the mini-wind turbine at Vilà Farm involving fourth year undergraduate engineering students at the University of Girona; (b) Vilà Ecofarm is an example of sustainable energy use and dissemination of sustainable energies

meteorological data that is suitable for computing wind-harvesting potential. Networking alignment is produced with wine producers, Ordis Council, and the University because outputs report benefits to all these institutions.

Contact with local entities also includes other private companies as SolarWorkCat that is in charge of the mini-wind generator placed at the village of Ordis (SolarWorkCat, 2019). Collaboration includes aspects such as the design of automated systems, data fusion transmission, and dissemination of results to the primary school of Ordis by developing activities and specific monitoring systems.

Usefulness of this case study regarding other universities

The research here developed can be adapted to other universities or high level education centres that are placed outside of big cities and have a strong relationship with country land. Policies have a strong influence on land use because land use planning and regulations restrict how land can be managed. Most of sustainable energy resources are related to the countryside, so land uses could augment existing weaknesses and create new ones as biodiversity loss and food sovereignty. Considering land use concern, contact with local public entities is proposed as a starting point to begin partnership because opinion of local people is relevant. The contribution of this paper is connected to how private and public partnerships with local entities may have a strong influence on the learning outcomes of students in the sustainable energy topic.

Contact with local public institutions with the aim of promoting the use of sustainable energy sources is the starting point. In this case, the collaboration is based on mini-wind generators but other sources of energy as photovoltaic, solar thermal, geothermal, etc. are also suitable issues according with local needs and possibilities. From the interest of local public and private entities, learning outcomes are aligned to social needs.

A simple SWOT (strengths, weaknesses, opportunities and threats) analysis is proposed as useful framework for analysing the research reported. It can help audience to focus on the case study outlined by remarking strengths, minimising threats and taking the greatest possible advantage of opportunities that can be inferred from this work. The SWOT analysis is presented in the next paragraphs.

Strengths:

- to improve the learning outcomes (real world approach);
- to increase the knowledge of the University professors;
- to promote the University and sustainable energies along the local region; and
- to help local entities to develop sustainable energies according to the social needs.

Weaknesses:

- lack of financial funds;
- activities outside the university campus: need of transport and time; and
- activities limited to a reduced number of students (few specific subjects related to sustainability and final degree projects).

Opportunities:

- to establish relationships between University and Public/Private entities;
- possibilities of new businesses for future graduate students; and
- to increase the partnership by an active network at all levels.

Threats:

- land use conflicts; and
- dependency on laws and regulations.

Conclusions

Synergies between universities and external entities must be explored. Contacts with local institutions become essential because local sustainable resources and social needs are aligned with the Sustainable Development. The partnership between the Ordis Council and the University of Girona has provided support for developing the use of the sustainable energy sources. A network for local sustainable development has been established and new partnership entities have been contacted which allows the collaboration and future research. Within this context, the Ordis Council is aware of the quality of life of their citizens as well as the influence towards their attitudes. For these reasons, divulgation of results among citizens is an important challenge.

Sustainable energies and climate change mitigation are important educational issues that universities should include in their curricula across a wide variety of different disciplines, including but not limited to STEM subjects. Without dedication to meeting this objective, society is unlikely to be able to meet the challenges associated with avoiding and ameliorating negative environmental externalities. In this work, it is focused on describing and exploring collaborations for sustainable energy which were pursued by the University of Girona. These collaborations were a win-win in the sense that they provided practical educational experiences to engineering undergraduates while realising important environmental and social objectives. A key message from these experiences is that sustainable energy sources do not pose unique engineering challenges in many respects. In this way, students pursuing degrees such as electrical engineering, industrial electronics, automation engineering and mechanical engineering, are able to develop research projects related to sustainable energy sources despite having followed curricula containing few specific subjects in this domain. There could be important implications of this observation in terms of increasing the number of engineering professionals who work on sustainable energy projects in the future. In addition, the teaching staff is gaining experience, creativity, effectivity and society engagement from the partnership. The learning process is relearned outside the university walls according to the social needs that arise from local entities.

The method presented allows active learning achievement through CA of outcomes with local community. Moreover, other university challenges, as the contribution to ethics values of the society (solidarity, openness and creativity) are considered by using this methodology. The authors wish that this case study can motivate other universities to search local partnership with public and private institutions with the aim of promoting sustainability.

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