COMMON LEARNING AND APPLICATIONS PLATFORM IN RENEWABLE ENERGY HIGHER EDUCATION

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Abstract

Given the current global energy crisis and the responsibility to remedy and maintain a clean environment, creating renewable energy specialists is a priority for higher education. The exchange of experience of specialists researching and exploiting different types of renewable sources contributes to enhancing the content of Master's programs in this field and to developing graduates' skills to effectively use the potential of renewable and alternative energy sources in different parts of the world. The present study highlights the results achieved by partners from two universities in Iceland and Romania in their collaboration to create a common learning platform for the master students in renewable energy. Students and professors from both universities participated in training, study and application programs in the field of geothermal energy, hydrogen production and electrochemical energy converters. The projects carried out by the students participating in the program highlighted their increased ability to provide solutions to current challenges related to the use of unconventional fuels, the use of hydrogen vehicles, hydrogen production and storage, the use of geothermal potential for hydrogen production. The common learning and applications platform can be used in training programs for specialists from different universities and can also be extended through collaboration with other providers of renewable energy master programs.

Keywords: Renewable energy, master programme, geothermal energy, hydrogen production.

1 INTRODUCTION

A comprehensive global fuel analysis by the IEA has shown that global greenhouse gas emissions from energy have risen to their highest level ever in 2021. Global energy-related carbon dioxide emissions reached 36.3 billion tonnes, registering a 6% increase in 2021, due to the recovery of the global economy after the Covid-19 crisis [1]. To reach net zero emissions by 2050, as proposed by the European Green Deal [2], and to secure the livelihoods of the entire world population, efforts to implement an energy policy must be accelerated. Developing a society based on sustainable energy remains the world's only option. This requires specialists with an interdisciplinary background in renewable energy, capable of embedding concepts of sustainability and a carbon-free world in new technological innovations. Renewable energy (RE) education has been implemented quite recent, in late 1990s in a lot of countries. Kandpal and Broman [3] have made a review of RE education and concluded among other things that a renewable energy specialist should be" creative and imaginative" in order to be able to develop appropriate green solutions for specific situations. The authors, also recommended the standardization of RE learning at different levels such as national, regional or global to facilitate technology transfer and exchange of know-how. Renewable energy education programs should provide a combination of theoretical knowledge as well as practical training for students (laboratory experiments, practical demonstrations of operational systems, field visits, virtual experiments, computer simulations and modelling) [3]. A lack of qualified human resources in RE was found, with a mismatch between the education offered and the demand from industry, particularly in the case of higher education courses offered in relation to the high demand for practical training from industry [4,5]. The IRENA study estimated that in 2020 the global number of renewable energy jobs was 12 million and that by 2030 it will increase to 38 million [6]. More training and interdisciplinary curricula will be needed to meet these labour market challenges. The training of specialists means the development of a sustainable education in this field, based on digital innovations and the exchange of good practices with institutions that have rich experience. Based on this need, two universities in Europe with experience in the field of renewable energy, University of Bucharest (UB) and Reykjavik University (RU), started in 2020 a collaboration to develop a learning platform for students in the Master of Renewable Energy. Two projects have been developed within the EEA Grants - Financial Mechanism 2014-2021, Projects of cooperation in university education, with the aim of increase the entrepreneurial and innovation capacity of education

ISBN: 978-84-09-49026-4

and training for master's students in sustainable energy. This paper presents the common educational platform for the renewable energies master program as an efficient framework for the transfer of good practices between these universities. Also, this work analyses the impact on the users of the platform and the prospects for its development and extension to other areas of RE, students and universities.

2 METHODOLOGY

Reykjavik University has a long-standing experience in co-operation in education and research related to sustainability, with an emphasis on sustainable energy. Also, RU is a good example in promoting the university-industry collaboration as a source of added economic value for the company. Iceland is well known to be a world leader in the use of geothermal energy for heating and electricity production. Iceland School of Energy (ISE) at RU offers international sustainable energy master's programs, focusing on practice, innovation and interdisciplinary thinking [7]. University of Bucharest has developed a master’s program in renewable sources for training specialists (Sources of Renewable and Alternative Energy - SERA) based on the experience of the researchers in the field of hydrogen generation and storage, electrochemical converters. Both universities have joined their experience in renewable and alternative energy production and created a common educational platform for students from these universities. Each university created the own blended course consisting of theoretical knowledge (e-learning section) and practical training (mobility of students). The e-courses have been created to provide the necessary education materials in RE using the respective learning management systems between the two universities (Canvas and Moodle). Here, recorded lectures, readings and other educational material were distributed. One modularized lecture series” ENERGY IN ICELAND” is presented on the topics of sustainable entrepreneurship and policy, geology, geothermal energy, hydroelectric power, and electric power systems. Each module will contain a lecture, two readings, and a short quiz based on both the lecture and the readings. Second modularized lecture series” ELECTROCHEMICAL ENERGY CONVERSION” explores the role of electrochemical converters in connection to renewable energy sources. A further section is devoted to simulating the static power flow behaviour of energy systems built around conventional and renewable electricity generators. The course is based on lectures, seminar/practical course, videos, remote lab, simulation using Phyton and short quizzes. Anytime students can schedule an on-line meeting with lecturers if there are any questions regarding the content. In conjunction with the Lecture Series, students are required to write a short report detailing their proposal for an innovative, sustainability-focused solution to a modern energy problem. Students must consider the financial, engineering, and social impact aspects of their innovative idea and detail these aspects in their report.

Students from each university (14 from RU and 15 from UB) were selected until now, to take the e-learning modules and also to participate to mobility in Iceland and Romania. The time allocated for each e-learning module was 1 month and 10 days for practical activities. Practical activities consist of field visits at geothermal reservoirs and power plants, hydro power plants, photovoltaic power plant, experimental laboratories, practical demonstrations of operational systems. At the end of these blended courses, students completed their personal projects. They also responded to a survey about their perception of their experience with the information provided and the learning methods used. Each student received a mark and a number of ECTS for completing the blended courses.

3 RESULTS AND DISCUSSION

The idea of creating a common platform for students studying renewables at UB and RU was driven by the need to increase their curricular scope by combining the different training and research experiences of the teaching staff from both universities. To this end, RU designed a course focused on experiential learning in geothermal energy exploitation and sustainable entrepreneurship. UB has developed a course related to the working principle of electrochemical energy converters and their role in creating the new energy system. The theoretical knowledge and a series of applications were uploaded into the Dynamic Learning Environment specific to each university. The field visits, practical demonstrations at different power plants and lab work followed after the students completed the e-learning part. Some of the materials developed for this purpose became open educational resources [8], after an evaluation process and feedback received from users.

3.1 Design of the learning and applications platform

For the development of the learning platform, the need to deliver the theoretical content of the courses online was the starting point of the project during the pandemic period. It was also desired that the information related to the experimental part be delivered using innovative teaching techniques. Therefore, we had prior discussions with the students to determine the best way to present the information [9]. We produced a series of video materials to explain the phenomena related to obtaining hydrogen by electrolysis and a remote laboratory for experiments related to electrodes and electrolytes. The scientific content is based on the experience gained by the lecturers from both universities in research and educational projects ([10], [11], [12], [13]). The applicative activities for a better understand of concepts in RE is provided through experimental labs and study visits in Iceland and Romania. This way of offering the courses and the applications in both online and offline is a novelty and reduces the risk of cancelling mobilities between countries due to unforeseen issues such as travel restrictions but also to promote a more sustainable exchange mechanism. In addition, more students have access to RE education and could travel, for shorter periods, in the same budget.

3.1.1 E-learning platform

Each lecture works as a platform for rapid learning. After going through the lecture and related materials, students are able to read and understand the main issues discussed in the related scientific literature. Students are then quizzed on their comprehension of this material. Registered students are provided online content on platform in the form a Lecture Series. This series is modularized (table 1). Each module contains: one and a half hours video lecture, associated lecture slides, up-to-date scientific articles related to the topic, a short quiz.

Table 1. Content of the e-learning platform.

Course 1/ Energy in Iceland		***Course 2/ Electrochemical energy conversion***	
Module	***Content***	***Module***	***Content***
Introduction to energy in Iceland	How natural forces have influenced the development of Iceland and its inhabitants. The lecture highlights and creates an understanding of the interplay between human activity and the environment.	Electrochemical energy converters	Fundamentals of electrochemical energy converters. How can electrochemical energy converters be integrated in the energy system? Electrochemical energy devices: from lab to market
Geothermal energy – Introduction	A broad overview of geothermal energy How geothermal energy is explored and utilized in Iceland and worldwide.	Membrane fuel cells	This course presents an overview of fuel cells and their relation to sustainable management of resources. Ion exchange membranes. Proton exchange membrane fuel cells (PEMFC.
Geothermal energy – Advanced	Types of geothermal systems. Classification of geothermal systems. Electricity generation processes. Challenges for geothermal electricity generation. Worldwide geothermal generation and geothermal jobs.	Static Power System Simulation using Python	How to use Jupyter Notebook and Python to simulate the static power flow behaviour of power systems build around conventional and renewable electrical energy generators. How to use already defined models for the European Network of Transmission System Operators and how to check the viability and find the optimal state of your defined networks.
Hydropower resources	Hydrologic cycle, electricity production, hydropower design, and types of hydropower plants and turbines.	Hydrogen production by electrolysis	Hydrogen production. Electrolysis- introduction and basic principles Electrodes: working electrode, reference electrode, counter electrodes. Electrochemical measurements.
Energy policy and entrepreneurship	The main themes driving energy policymaking by focusing on the why from a political, economic, and planning perspective and environmental perspectives through the lens of environmental resource economics.	Phenomenological study of electrolysis of water	Hydrogen production from renewable resources. Experimental part. Video

Electric power systems & renewable generation	Fundamental laws of physics that govern power systems. Structure and major components of a modern power system. Characteristics of different types generation. Concepts in reliability and resilience. Power system architectures and microgrids.	Remote laboratory	Role of the electrolyte solutions in the electrolyze process and the utility of reference electrode in electrochemical measurements.

Following the 2 courses, students will explore the many areas associated with renewable energy and sustainable development. Students will achieve a fundamental understanding of geothermal energy use, hydropower, electrochemical energy conversion and energy policy. The role of electrochemical energy converters will be explored in connection to renewable energy sources. Also, the students will be able to use Jupyter Notebook and Python to simulate the static power flow behaviour of power systems build around conventional and renewable electrical energy generators.

3.1.2 Applications platform. Open resources

Knowledge through experience is very important for understanding theoretical concepts, so another component of the platform is its application part. We have designed some educational resources that give students the possibility to create their own lab and also to use a remote set-up. We made two videos, as complementary to lectures in an academic setting (Electrolysis Part 1: Electrolysis at Home, Electrolysis Part 2: Electrolysis in the Laboratory) useful to students for their own experience related to the production of hydrogen by electrolysis.

The great challenge of this project was the need to adapt classroom and laboratory education to online teaching. An innovative method in this field was the building of a remote laboratory (Fig.1) for students to experiment with the production of hydrogen by electrolysis and other aspects related to electrochemical converters. We developed an experimental framework that can be used as a hands-on and remote laboratory by students interested in STEM and especially renewable energy [14]. To perform the experiment, students will login to a website. By logging in, they will receive control over the experimental setup, so that they will be able to set up the experiment, modify the parameters and obtain the row data. These experimental data will be downloaded and processed just like a hands-on experiment. The complexity of the educational resources follows the natural learning curve, starting with the basic observation of a phenomenon, followed by an understanding of the underlying physics and then the interpretation of experimental data from which students draw their own conclusions and provide contributions to the development of the field. This increases student engagement and generates a motivation to repeat the experiment at home.

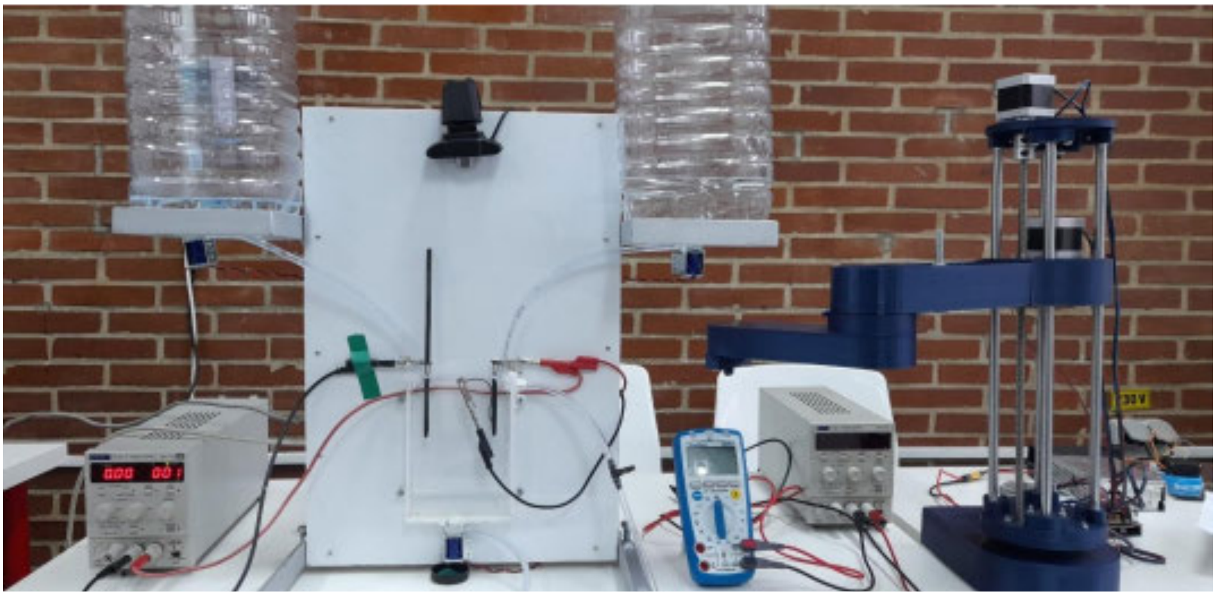

Figure 1. Remote laboratory for electrolysis experiment.

3.2 Analysis of the platform efficiency

We analyzed the efficiency of the learning platform based on the following criteria: the grades obtained for the blended courses; originality of the proposal for an innovative, sustainability-focused solution to a modern energy problem; the students' answers to the survey.

The majority of students achieved grades of 10/A (52%) and 9/B (34%). There are also grades of 8/C, 7/C and 6/D in a small percentage, below 14%. These results show the advantages of these blended courses: the flexibility that offers the benefit of deep understanding of certain topics without time pressure, the lots of feedback and the straight forward.

The RU students' final reports provided in-depth analyses of the opportunity to use hydrogen produced from renewable energies as a fuel in all types of transport to replace fossil fuels. The current trends in hydrogen production, storage and utilisation were reviewed from the perspective of an automotive energy carrier. Where hydrogen can be produced using only green energy sources for example, wind, solar or biomass, the entire life cycle of a vehicle powered by a hydrogen fuel cell has the potential of having a net zero effect on the environment. They identified some technical, economic, social and political barriers to the widespread use of hydrogen as a fuel. Also, they propose solutions to succeed as information campaigns to raise public awareness and create a positive attitude towards hydrogen vehicles, government policies and funding to support development, and strong regulations in the field.

The final reports submitted by UB students at RU offer a comprehensive examination of sustainable solutions to energy issues facing Romania. The scope of the research encompasses a wide range of topics of interest to the field of energy and sustainability, including the provision of sustainable power solutions for electric vehicles, the implementation of sustainable energy practices in the healthcare industry, the availability of affordable and clean heating options, and the advancement of renewable energy in educational facilities. In their research, the students identified current problems and limitations within these areas of focus. Through an in-depth analysis of the technical, economic, and social impacts of these issues, they have also conducted a thorough examination of relevant policy, referencing resources from the course materials as well as field visits. The projects submitted by the students demonstrate a solid understanding of the challenges facing the development of renewable energy in Romania, and offer valuable insights into potential pathways towards solutions.

Students participating in the survey appreciated the blending of e-learning and applications, because it offers them the opportunity to study at their own rate, to deepen, to ask questions and also to experiment in the field or in study visits. Particularly in the time of online education, having the opportunity to acquire information through one's own experience, in a scientifically valid framework, is very valuable for young people. The video labs and the remote lab were valued by our students and all those who accessed the open access documents available on the dedicated website [8] (were around 400 visits per month and a total average viewing time of 16 hours). But at the same time students found that the practical experience gained in the labs and field visits made a major contribution to their understanding of the subject. Students also appreciate the success of the course in developing their own projects related to the implementation of RE in their areas of origin. According to the survey the practical applications during the mobility helped students to develop many personal skills, the ability to work in a competitive environment but also in an international team, critical thinking, flexibility and also time management. Students are aware that the links that have been established with people involved in other renewable energy projects represent an opportunity for the development of joint projects.

The results of the survey support the conclusion of Gutiérreza et al. [15] that the international context of study and the diversity of lectures can be used as pedagogical methods for the development of RE higher education.

The teaching staff involved in the project exchanged information related to teaching methods, working visits, laboratories, professional practice to economic partners. Thus, during the project, both partners got in touch with stakeholders from the two countries, who better understood the specifics of qualification in RE. Starting from here, new partnerships are established within the countries but also with other European countries for joint projects in renewable energies and energy efficiency.

4 CONCLUSIONS

The collaboration of two universities from Europe led to the development of new study disciplines for master students involved in RE in Romania and Iceland.

The development of a common learning and applications platform led to the expansion of the knowledge regarding different sources of renewable energy of the students from both universities, to the elaboration of educational resources that can be used by future specialists in this field, from any part of the world. Students who benefited from blended courses had the chance to increase their knowledge in RE, to use new teaching methods, to work in international teams to find local and global energy solutions.

The exchange of experience of specialists researching and exploiting different types of renewable energy sources contributes to improving the content of Master's programs in this field and developing graduates' abilities to effectively use the potential of renewable and alternative energy sources in different parts of the world. Combining the renewable energy expertise of partner universities, through the mobility of students for traineeship and study and the mobility of staff involved in renewable energy Masters programs, contributes to enhancing the efforts of the transition towards sustainable energy sources. The common learning platform could be expanded by joining other European universities with expertise in RE.

Sharing a common philosophy on sustainability and energy efficiency, based on the exchange of students, teachers and best practices between universities with expertise in renewable energy, leads to accelerating the transition to a carbon-free world.

ACKNOWLEDGEMENTS

This work was supported by a grant from the EEA Financial Mechanism 2014-2021, Projects of cooperation in university education “Education, Scholarships, Apprenticeship and Youth Entrepreneurship Program in Romania”, the project number 21-COP-0021, “Sustainability in education for green energy specialists” (http://sera.unibuc.ro/seges). The project is a cooperation between two partners: the Faculty of Physics at the University of Bucharest and the Iceland School of Energy at Reykjavik University. Its content does not reflect the official opinion of the Program Operator, the National Contact Point or the Office of the Financial Mechanism. The information and opinions expressed are the sole responsibility of the authors.

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