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Building a Renewable Energy Curriculum for Universities in Burundi

Dr. Pritpal Singh, Villanova University

Dr. Pritpal Singh is Professor of Electrical and Computer Engineering at Villanova University. He received a BSc in Physics from the University of Birmingham, UK in 1978, and Masters and Ph.D. degrees in Applied Sciences/Electrical Engineering from the University of Delaware. He has been actively working in developing countries to educate students and professors on topics of open source hardware/software, electronics and renewable energy.

Agnes Nakimana
Chris Clement Igiraneza

Building an Undergraduate Renewable Energy Curriculum for Higher Education Institutions in Burundi

Pritpal Singh, PhD, Agnes Nakimana, PhD, and Chris Clement Igiraneza, Ir Msc

Abstract:

Burundi is emerging from years of political instability and negative economic growth to a more stable and growing economy. This is attracting external investment into the country. Nevertheless, at present, only 10% of the population has access to electricity, with most of the population having access residing in the capital city of Bujumbura. There is a large opportunity for renewable energy deployment in this country with the entry of a green financing organization into the country. The Ministry of Energy in Burundi established an Energy Efficiency office five years ago but it has not been active due to the lack of adequate expertise and data in the domain. While many renewable energy curricula exist throughout the world, and in sub-Saharan Africa in particular, there is no curriculum that has been developed and implemented for the Burundian context. To better understand the needs of higher education institutions in Burundi, Prof. Singh visited the country and delivered a workshop at Ecole Normale Supérieure (ENS) in December 2022.

In this paper, we present the objectives of a renewable energy curriculum adapted to the Burundian context, present the renewable energy workshop delivered to professors and students in Burundi, and describe the structure of a renewable energy curriculum proposed for higher education institutions and universities in the country.

Introduction

About 770 million people in the world do not have access to electricity [1]. Of this population 597 million live in sub-Saharan Africa [1]. The opportunity for providing off-grid access to electricity to rural communities has been demonstrated through solar powered mini-grids [2,3]. These systems typically comprise a set of solar panels, batteries to provide electricity when solar power is not available, e.g. at night, and may employ a fossil-fueled generator to also provide backup power. While mini-grids of this type are starting to provide access to electricity in communities, there are many limitations that are currently limiting their wider deployment. In particular, the educational systems in many sub-Saharan African countries do not offer renewable energy courses. Furthermore, skills around writing proposals to acquire funding to finance these systems, basic project management skills around deploying and implementing renewable energy systems and developing sustainable business models to ensure that the productive use of the generated electricity provides sufficient income to sustain a renewable energy enterprise are often not incorporated into education curricula. This paper considers a new renewable energy curriculum for the Burundian context that includes these components.

Review of Existing Renewable Energy Programs in Sub-Saharan Africa

Several renewable energy masters' programs are offered in Sub-Saharan universities that have been adapted from other countries, e.g. Sweden in the global north. As reported in the University World News, Africa Edition, "a master's in renewable energy is offered by about 20 African universities such as the University of Zimbabwe, Makerere University in Uganda, the University of Dar es Salaam in Tanzania and Mekelle University in Ethiopia." [4] The College of Engineering, Design, Art, and Technology at Makerere University in Uganda hosts a master's in renewable energy program that offers various specializations including bioenergy, hydroelectric power, solar power, wind power and energy efficient

building systems tracks. They include courses in the technologies themselves as well as project management classes. Their program goal is to train up to ten students per year to become managers in the emerging renewable energy sector in Uganda [5].

A renewable energy master's program as well as a solar energy research center has been set up at Strathmore University in Nairobi [6]. They have established an excellent training lab for renewable energy technicians with significant training equipment, including solar panels, multi-kilowatt DC-AC inverters, batteries, etc. provided by various companies, including Siemens Corporation. There is also research being performed at the solar energy research center at the university. Prof. Izael da Silva who directs the research center has been very successful in securing European funding to support this research center.

While there are several examples of master's level programs in sub-Saharan African universities, there are relatively few undergraduate renewable energy programs offered at universities in this region of the world. In a recent paper in the Cleaner Engineering and Technology journal, authors from four different universities in Nigeria conducted a survey of undergraduate engineering students at two universities in Nigeria – the University of Ibadan and the University of Benin - on their perceptions and awareness of renewable energy and the environmental and climate change impacts of burning fossil fuels [7]. The results of the surveys showed that 76% of respondents agreed that renewable energy was not part of their undergraduate course work. Furthermore, the survey responses indicated that "*64.8% of respondents claim not to have heard of the Paris climate agreement and 37% said they have never heard of the sustainable development goals of the United Nations*"! Nevertheless, "*90.7% of respondents want renewable energy to be added to their undergraduate curriculum*". Since Nigeria is dominated by oil and gas industries, these results are not surprising.

In their paper, "An African-European network of design universities fostering the goal of sustainable energy for all", the authors from three European universities (Politecnica di Milano, Italy, Brunel University, UK, and Delft University of Technology, the Netherlands) and four African universities (Cape Peninsula University, South Africa, University of Nairobi, Kenya, University of Botswana, Botswana and Makerere University, Uganda) describe an innovative approach to curriculum design in the area of "*Design for Sustainability (DfS) focused on Distributed Renewable Energy (DRE) and Sustainable Product-Service Systems (S.PSS)*" [8].

In their paper "*Rethinking education for SDG 7: A framework for embedding gender and critical skills in energy access masters programmes in Africa*", Pailman and de Groot of the University of Cape Town describe how renewable energy education programs need to pay attention to developing skills. [9]

In their review of renewable energy education globally, Kandpal and Broman of Stromstad University in Sweden describe some key learning objectives of university courses in renewable energy [10]. These are listed below quoted verbatim from their paper:

"(a) It should cover all renewable energy resources with particular emphasis (if needed) on some specific ones depending upon the local needs and resource availability characteristics.

(b) It should cover all aspects relevant to the development and dissemination of renewable energy technologies such as (i) resource assessment, (ii) design, manufacture, installation, performance monitoring, trouble shooting and maintenance of technologies, (iii) financial, economic and energetic

aspects of renewable energy technology utilization, (iv) socio-cultural acceptability and (v) assessment of associated environmental impacts.

(c) It should establish synergy with energy conservation (wherever applicable) and energy–environment interaction related inputs to the students.

(d) It should provide a balance between theory and practical aspects. Therefore, its curricula should include inputs on laboratory and demonstration experiments, hands-on-skills training, trouble-shooting, design and manufacture inputs besides lectures, tutorials, assignment and seminar, etc.

(e) It should be flexible and dynamic thus allowing for future improvements in the content and structure of teaching/training programme.

(f) It should be compatible with global efforts to facilitate effective and mutually beneficial experience sharing and interaction with other institutions in the world.

(g) To the extent possible, the university level teaching/training programmes on renewable energy education in particular and all other initiatives, in general, must ensure employment/self-employment to the students upon successful completion.

(h) It should preferably be provided in local languages for better acceptance and efficacy (good quality teaching–learning resources materials should also be available in local languages at affordable prices)."

The Burundi Context

Burundi is located in East Africa at a latitude of 3°S (below the equator). As an economy, Burundi has seen steady growth over the last five years and is starting to attract significant foreign investment. It has a plentiful supply of rainfall and solar irradiance which makes it ideal for hydroelectric and solar energy systems. However, at present, only 11% of the population has access to electricity with most of this population located in the capital city of Bujumbura (only 3% of the rural population has access to electricity) [11]. The primary source of this electricity is hydroelectricity. There is significant scope for Burundians to develop solar energy due to the availability of high intensity solar radiation throughout the year. However, there is a lack of adequate expertise in Burundi to exploit this renewable energy resource.

The higher education system in Burundi includes public and private universities who educate Burundian people through several programs. Presently, no university in Burundi is offering degree programs in renewable energy at either the undergraduate or post-graduate level. With the recent political stability in the country, the GDP has been growing slowly at a rate of 1.5-2.0%/year based on World Bank data [12]. Furthermore, there is growing interest in investing in Burundi since there is significant growth potential, particularly in the energy sector. European green bank financing for renewable energy projects entered Burundi in November 2021. This is therefore an opportune time to invest in capacity building in renewable energy in Burundi.

Partnership with Kit Hub

KIT HUB (Knowledge and Impact Trade) is a philanthropic, non-profit organization established by Chris Igiraneza based in Bujumbura. Its mission is focused on the democratization of knowledge and

opportunities in Burundi, and to create social impact to make the Burundian people more educated, qualified, and prosperous.

KIT Hub educates, inspires, and supports the Burundian people through several programs with a particular focus on youth and women with innovative ideas, and whose activities focus on inclusive and entrepreneurial digital transformation. More details about the organization are available at its website [13].

The renewable energy sector presents multitude opportunities to innovate in the country as well as create jobs for many people. Furthermore, KIT Hub believes that sustainable education is a path to innovation and employability in the country. Hence, KIT Hub is involved in creating curriculum that will merge Information and Communication Technology (ICT) and Renewable energy for people in Burundi.

Prof. Singh and Chris Igiraneza received a grant of $5,000 from the IEEE Humanitarian Activities Committee (HAC) to support a train-the-trainer workshop on renewable energy for professors and students at universities in Burundi. The project funds also provided for the acquisition and installation of a 1kW solar electric system to be deployed at the campus of one of the universities in Burundi.

Chris Igiraneza coordinated the recruitment of the students/professors for the workshops and received most interest from Prof. Agnes Nakimana, Research Director at Ecole Normale Supérieure (ENS). Based on this interest expressed by Prof. Nakimana, it was decided that the renewable energy workshop would be conducted at this university and the 1kW solar electric system would be installed on this campus. Chris Igiraneza also coordinated the purchase of the solar electric system components and the logistics of delivering these components to ENS.

Ecole Normale Supérieure (ENS)

Ecole Normale Supérieure (ENS) was created in 1999 with bachelor's degree programs offered through three departments. Its mission is to produce teachers of general and technical high schools. Recently, the Applied Sciences Department added a master's degree program to their offerings. Within those programs, elementary courses of renewable energy are given because, among ENS's teachers, even elsewhere within Burundi, no one is really a specialist in the sector. Furthermore, no research about renewable energy is being conducted at ENS or at other institutes of higher education in Burundi. Some people need to install solar panels, but no one has the skills to help them to choose good equipment, to install them well, and to maintain the equipment as needed. By starting a program of renewable energy at ENS it addresses an important and urgent national need. The graduates from such a program would help in the process of development of renewable energy in Burundi and could conduct some research to improve the efficiency of that technology within the Burundian context.

Renewable Energy Workshop for Burundian Professors and Students

Professor Singh offered a workshop on renewable energy in Burundi from November 2022 to March 2023. The program started with three online classes offered over Zoom from Villanova University during the months of November and December 2022. These classes were typical 1.5 hours in length and were offered at about 5:30 p.m. Burundi time, after the professors had finished teaching their classes for the day. The topics covered in these initial three classes were:

1. Introduction to Electrical Energy
2. Introduction to Renewable Energy

3. Overview of the Solar Resource

A total of about ten professors and master's students from ENS attended the classes. Since several of the students were not from electrical engineering backgrounds, it was important to introduce some basic concepts of electrical energy to the entire class. It also provided an opportunity for those students who had familiarity with the topical material to learn it in English since the main language of education in Burundi is French (although the students taking the class did understand English).

The introduction to renewable energy class introduced the topics of solar energy, wind power, and small-scale hydroelectric power and examples of off-grid systems were presented to show examples of how such technologies could be used in the Burundian context. Furthermore, case studies showing how these different technologies could be used to support local sustainable economic development were also presented.

The third class on the solar resource presented the available solar resource at different times of the year and how to assess the amount of solar radiation available for conversion to electricity at any location and day of the year (as well as time of day). Example problems were also covered in this class.

In December 2022, Prof. Singh traveled to Bujumbura to deliver classes in person as well as to work with the local students to do practical work related to the characterization and deployment of a solar electric system on the ENS campus.

Two classes were offered in person on the topics of solar panel technology and off-grid, stand-alone solar electric system design. In the class on solar panel technology, students learned how solar panels work, how their performance changes with temperature and light intensity, and how to characterize the solar panels.

In the class on off-grid, stand-alone solar electric system design, the students learned how to design a complete off-grid solar electric system. The different components, including charge controller, solar panels, electrical loads, DC-AC inverter, and batteries were described and how a complete system could be designed to meet particular load requirements.

The remaining time of the in-country workshop was spent in practical design and implementation of a solar electric system on the ENS campus. Prior to arriving in Burundi, Chris Igiraneza, organized the acquisition of the solar electric system components to be used in the ENS deployment. This included four 250W solar panels, four 200Ah lead acid batteries, and a combined charge controller/inverter. The original plan was to purchase these from an experienced dealer in Kenya. However, due to some complications with the logistics of importing solar equipment from Kenya into Burundi and the tight timeline to acquire the components, the decision was made to purchase the materials locally. Unfortunately, the locally available materials in Burundi were not of the high quality available from Kenya. Furthermore, missing components, such as solar combiner boxes and disconnect switches were not available from local suppliers. As a result, the technicians creatively worked around these issues to incorporate locally available parts for completing the installation of the system. Nevertheless, this experience highlighted the lack of supply chain of high-quality components for installing solar electric systems in Burundi.

In the practical work that the students engaged in during the workshop, they completed several tasks. The first was to verify the solar panel current and voltage outputs. A photograph showing the students making these solar panel characterization measurements is shown in Figure 1. A second task was to select a site for locating the solar electric system. After careful consideration, a site outside one of the administrative buildings was selected. A third activity performed by the students was to estimate the load. It was decided that an office would be supplied with the power from this solar electric system. The students went to the office and catalogued the number of electrical devices, including desktop computers, printers, photocopying machines, etc. being used in the office to estimate the load requirements for the system. A fourth task was for the students to lay out the system including locating the solar panels and batteries and where to mount the charge controller/inverter and how to connect to the distribution panel for the building. They measured the length of wiring needed for the system and calculated the gauge of wiring based on the length and proposed maximum voltage drop to be tolerated in the wiring. Additionally, the students had to calculate the tilt angle of the solar panels and then design the mounting frame for the solar panels accordingly. Once the students had completed the system design, local technicians skilled in welding were brought in to fabricate the mounting structure and electricians were brought in to wire up the system. The complete 1kW solar electric system was installed within a few days. A picture of a local electricians and ENS professors wiring up the solar panels located in the mounting structure set up by mechanical technicians is shown in Figure 2.

Following the practical workshop and installation of the solar electric system at ENS, Prof. Singh offered one more class remotely from Villanova on the design of solar water pumping systems. This is an important topic in Burundi because Burundi's economy is strongly based on agriculture. By designing and installing solar powered irrigation systems on farms, there is an opportunity to increase the yield of farms.

A final workshop was delivered in March 2023, in which Prof. Singh showed the students how to use the commercial software tool, PV Syst, for designing and analyzing solar electric systems.

Figure 1. Professors and students at ENS characterizing a solar panel

Figure 2. Professors and Electrician Wiring up Solar Panels

Undergraduate Electrical Engineering Curriculum at ENS

The four-year baccalaureate degree in electrical engineering at ENS is structured as shown in Table 1. The first year is comprised of basic science and mathematics classes as well as introduction to engineering design. In the second year, students are introduced to renewable and non-renewable energy sources as well as taking their basic electrical engineering classes as well as courses in psychology relevant to the mission of preparing teachers for education careers. The subsequent years continue to develop the students' knowledge in both their electrical engineering discipline as well as educational pedagogy.

Table 1. ENS Electrical Engineering Bachelor's degree curriculum

	Semester 1	Semester 2
Year 1	Communications and Citizenship	Information Science
	Fundamentals of Science	Mathematical Simulation
	Mathematical Sciences	Fluid Mechanics and General Chemistry
	Engineering Design 1	Electricity and Magnetism
		Specialized Communication (Braille and Sign Language)
Year 2	Psychology 1	Psychology 2
	Energy Production – renewable and non-renewable energy sources	Engineering Design 2
	Basic Electronics	Electrotechnology

	Circuits and Control Systems	Electric Circuits and Electrical Equipment
	Materials and Assembly	Mechanics
Year 3	Educational Pedagogy	Educational Practices
	Electric Power Networks	Digital Control Systems
	Thermodynamics	Electrical Energy Utilization
	Reliability of Electrical Networks	Practical Electricity
Year 4	Ethics and School Administration	Thermal Modeling and Control
	Didactic	Electric Networks and Installation Practice
	English Language and Environmental Protection	Organization and Industrial Legislation
	Professional Practice	Entrepreneurship

While the students have an introductory course in their second year that introduces the concepts of renewable energy, the course is very basic and limited in scope. It is also very theoretical with no practical component. While there is also an introductory course on entrepreneurship in the final year of the curriculum the students learn very little about business principles and business plan development.

Proposed Renewable Energy Curriculum

There are several gaps in the present curriculum related to renewable energy content as identified by Profs. Nakimana and Singh. In partnership, they found that there needs to be coverage in the curriculum on the following topics:

- Detailed design of renewable energy systems, including solar electric systems, wind energy systems, and biomass energy systems
- Practical knowledge of solar electric systems
- Understanding how to use software tools to size solar electric systems
- Energy Efficiency and Conducting Energy Audits
- Power electronics
- Project Management, including business accounting and financial management of projects
- Obtaining financing for renewable energy projects
- Monitoring and evaluation of off-grid renewable energy systems
- Energy policy drivers

To accommodate these topics into a new curriculum focused on preparing students to be renewable energy entrepreneurs, we needed to design a new curriculum for undergraduate electrical engineering students for Burundian universities, modeled on the ENS curriculum. This was done in partnership between Profs. Nakimana and Singh.

Table 2 shows a potential revised electrical engineering curriculum that would accommodate these topics and remove topics not necessarily relevant to renewable energy systems.

Table 2: Proposed Curriculum for a new bachelor's degree in Renewable Energy

	Semester 1	Semester 2
Year 1	Communications and Citizenship	Information Science
	Fundamentals of Science	Mathematical Simulation
	Mathematical Sciences	Fluid Mechanics and General Chemistry
	Engineering Design 1	Electricity and Magnetism
		Specialized Communication (Braille and Sign Language)
Year 2	Psychology 1	Psychology 2
	Energy Production – renewable and non-renewable energy sources	Engineering Design 2
	Basic Electronics	Electrotechnology
	Circuits and Control Systems	Electric Circuits and Electrical Equipment
	Materials and Assembly	Energy Efficiency and Conducting Energy Audits
Year 3	Educational Pedagogy	Educational Practices
	Electric Power Networks	Digital Control Systems
	Thermodynamics	Electrical Energy Utilization
	Reliability of Electrical Networks	Practical Solar Electricity
Year 4	Ethics and School Administration	Solar Electric System Modeling
	Didactic	Power Electronics
	English Language and Environmental Protection (including renewable energy policy)	Project Management (including monitoring and evaluation of off-grid solar electric systems)
	Professional Practice	Entrepreneurship (including financing of renewable energy systems)

This curriculum would serve the needs of the target audience, namely students who are potentially going to develop renewable energy projects in Burundi and are potentially going to teach high school students to prepare them for higher education in this subject area.

Conclusions

Emerging out of several years of low economic growth, it is an opportune time to invest in Burundi. A critical need in the country is access to electricity, an enabling technology that allows for improvements in education, connectivity, health, and economic development. Yet, the lack of expertise in energy technologies, particularly renewable energy technologies, in Burundi is a limitation to achieving these development advancements.

In this paper, we have presented a proposed initial renewable energy curriculum modeled on the electrical engineering curriculum at ENS. The proposed curriculum is designed to meet the needs of students within the Burundian educational context.

The next steps are to prepare detailed descriptions of the proposed new courses to be offered and to develop plans for implementation of the new program.

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