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Master's final projects as an approach to sustainable development of local communities: Experiences from the electrical engineering program at Universidad Politecnica Salesiana Guayaquil

Christopher Reyes-Lopez, M.SC.[1], José Jaime-Carriel M.SC.[1], and David Cortez-Saravia M.SC.[1]
[1]Universidad Politécnica Salesiana Sede Guayaquil (SMART-TECH), Ecuador, creyesl@ups.edu.ec, jjaime@ups.edu.ec, dcortezs@ups.edu.ec

Abstract*– Rural areas in developing countries often hold an abundance of natural supplies; most of these resources are not appropriately exploited, at least not to support the community's progress and its people. The Salesian Polytechnic University of Ecuador (Universidad Politecnica Salesiana de Ecuador - UPS) has always been involved in funding and executing short and long-term projects of such a diverse nature for the assistance to less-favored communities. Students from the master's program in electrical engineering, specifically at the branch located in Guayaquil, have been proposed to make their final projects on topics related to renewable energies, and smart grids, which may be employed to help small rural populations. In this context, this manuscript allows to understand the importance of carrying out a variety of master's final projects on topics of power and energy engineering to boost the sustainable development of underserved localities, especially in rural areas. After the implementation and simulation of the projects under study, the outcome of this theoretical contribution makes it possible to recognize that universities are a key factor in promoting the growth of local economies and people's lives in rural communities, as mentioned by interviewees in remarkable testimonials.

Keywords*-- Sustainable local development, master's final projects, renewable energy generation, electrification of less favored communities, community participation.

I. Introduction

The dependence of countries on the import of electricity at high prices to supply their territory seems to be a never-ending lucrative business for energy producers around the world. However, it is an unpleasant reality for the purchasing country, in particular for those that have an abundance of renewable energy sources, such as the sun, winds, tides, and biomass. Therefore, a revision and update of governmental policies on power generation and supply, as well as on national and international investment, are urgent as indicated in recent research carried out in countries such as Palestine by Damayra & Khatib in 2022 [1], Bangladesh by Das et al. in 2018 [2], and Lithuania by Norvaiša & Galinis in 2016 [3].

Although renewable energy entrepreneurs are eager to promote and contribute to energy justice, meaning that they tend to offer their service to less-favored groups through the supply of affordable but efficient energy to the consumers, they must face several governmental restrictions and legal challenges thus far [4], [5]. Nevertheless, several countries have already opted for better policies and regulations on the appropriate exploitation of natural resources as an opportunity to generate clean energy [6]–[8].

There exist numerous projects abroad that focus on the best side of renewable power and present comparisons of its generation among different countries in several regions of the world. Some consider topics on sustainable generation [9], economic growth [10], investment [11], ecological footprint reduction versus economic growth [12], greenhouse gases emission [13], social equity [14], and vulnerable community empowerment and societal challenges [15]. The adoption of renewable energy systems can help mitigate the environmental impacts of traditional energy sources and promote economic development while providing a reliable source of electricity to the local population.

However, despite its recognized advantages, renewable energy generation could cause side effects on human health and nature [16], just to mention water and soil poisoning, river flooding or dry-up, and deforestation, among others. Moreover, a cooperative research conducted between universities of Bangladesh and Australia exposes an extensive review of data summarizing the negative effects of renewable energy generation, including solar, wind, biomass, geothermal, hydroelectric, oceanic, and osmotic origins [17]. For this reason, a proper planning analysis that includes environmental risks must be carried out before the deployment of any renewable power plant, no matter the source.

In recent years, the importance of sustainable development has become increasingly apparent, and renewable energy is a crucial aspect of achieving it. The basics of sustainability stipulate three pillars: economic viability, environmental protection, and social equity (Candelaria et al., 2023; Sala et al., 2015), which make any renewable energy exploitation an important key to contributing to local development. Renewable energy systems are a sustainable, clean, and cost-effective method of generating electricity that may give several benefits to local communities.

For instance, the research presented by Gonçalves, Rodrigues, and Chagas shows that wind power has positively influenced the Brazilian labor market [18], including the boost of employment opportunities in diverse industries, such as

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energy, agriculture, and construction. In addition, it has not only raised the wages in all economic sectors, but it also has caused a substantial social impact by contributing to local development and social welfare increment.

A very noteworthy example comes from the Southeast Asian region. Vietnam has experienced a vertiginous deployment of solar and wind power generation since 2019, which has made the country succeed in exceeding its envisioned green energy production for the year 2020. This is the great consequence of a comprehensive effort to attain energy sustainability via the involvement of the government, the industry, and the public [19].

A study developed by Bertheau examines the positive impact of the implementation of comprehensive solar power systems in the Cobrador Island of The Philippines. The combination of these isolated solar projects has a huge influence on local development, which has included the enhancement of access to education and health services, but also an improvement of safety, according to surveyed participants. Additionally, it is found that some families are taking advantage of electricity to raise, to some extent, their household income [20].

In Ecuador, the policies and the regulatory framework of energies are ruled by the Ministry of Energy and Non-Renewable Natural Resources. This country has experienced a favorable unfoldment of renewables during the last decade thanks to the release of national guidelines that support their implementation, especially in vulnerable areas. Some studies show the gradual insertion of renewable sources into the Ecuadorian energy system, as well as an analysis of the projects carried out by the Government to accomplish the objectives defined in the Master Plan of Electrification for the period between 2013 and 2022 [21], [22].

Moreover, the implementation of renewable energy systems in local communities of Ecuador can provide a reliable source of electricity, particularly in remote areas where the main power grid does not reach [21]. The reliability of clean energy can help to improve the quality of life of local communities, supporting economic development by powering small businesses, homes, and schools. In addition, these systems can be installed quickly and easily, making it possible to provide electricity to areas without access to the national power grid.

Notwithstanding the benefits that implementing renewable energy could bring, not only to less-favored communities of Ecuador, but to the whole country, most of the national electrical engineering programs did not include courses that cover such technologies in their curricula. It was just in 2019, when undergraduate programs went through a reduction of one academic year, this means, going from five to four years of duration, that an important curriculum update took place. The electrical engineering programs experienced positive modifications through the inclusion of courses that cover renewable energy and sustainable development [23], [24]. The resultants are a curriculum more aligned with the requirements of the national energy sector, and the future professionals well prepared to fit in a world each day more concerned with society and the environment [25].

Under the previous premise, every course imparted in any graduate program offered in Ecuador, or everywhere else, should teach the profound analysis of the most relevant governmental policies associated with their professional background, including how to make use of them in different scenarios. It should be mandatory that graduate students be able to apply policies and regulations for the sustainable development of the country [26]. In this context, the present research explores how the development of the final projects of the three class years of the master's in electrical engineering (MEL) offered by the UPS is a tool to support the sustainable development of local communities.

The manuscript is divided into four sections. The first one presents the theoretical framework based on recent research that allows this paper to set its relevance to the field of graduate education for sustainable development. The second section establishes the methodology used for data handling and analysis procedures. The third introduces the results of the project, which include testimonials of people who live in the localities intervened. Lastly, the fourth section puts the conclusion about the findings in sight.

II. Methodology

Research shows that electrical projects may influence the sustainable development of local communities (Algarni et al., 2023; Lillo et al., 2021). Based on the three pillars of sustainability and the outcomes of published studies, the MEL's final projects are grouped into five dimensions: renewable energy (RE), electrification of less favored communities (Community electrification - CE), reduction of social inequalities (Social impact - SI), local economic benefits (Local Benefits - LB), and community participation (CP).

This project bases its execution on the qualitative research method. A content analysis is performed to recognize to what extent the project fits into any of these dimensions. One project is allowed to be part of one or more dimensions at the same time. The sampling for this paper comes from the completed final projects of the three class years of the MEL. Nevertheless, only those responding to at least one of the five dimensions proposed were selected.

Additionally, it presents an exploratory research that considers interviews and focus groups to collect the data because of the small number of participants. The face-to-face survey follows a pen-and-paper personal interview method. The open-ended nature of the questions makes the data respond to the observational collection method. The questionnaires were organized bearing in mind the two different groups of people involved: energy-sector employees and beneficiaries.

On the one hand, the energy-sector employees include those who work directly at the producers of electricity, the National Electricity Corporation (CNEL for its name in Spanish), and at the regulator of electricity, the Electric

Corporation of Ecuador (CELEC for its name in Spanish). These interviewees had to answer a small questionnaire containing the questions presented in table 1.

TABLE I
QUESTIONNAIRE FOR THE ENERGY-SECTOR EMPLOYEES

How do the master's projects address the integration of local renewable energy sources into the national energy grid?
What impact do these initiatives have on promoting sustainability within less-favored communities?
In what ways do the projects focus on contributing to a more sustainable energy infrastructure within local communities?
In what ways do the master's projects contribute to the long-term sustainability and development of the local community?
How do the projects contribute to enhancing the resilience and reliability of the local energy infrastructure, especially by addressing current and future energy challenges?
How are the master's projects designed to engage and educate local communities about sustainable energy practices, and to enhance community awareness and participation in sustainable energy solutions?
Will the consumer be able to achieve a considerable reduction in the value of their electricity bills?

On the other, direct beneficiaries, that is, the inhabitants of vulnerable communities in the coastal region of Ecuador. The respondents had to answer a small questionnaire containing the questions presented in table 2.

TABLE II
QUESTIONNAIRE FOR THE DIRECT BENEFICIARIES

What aspects did you know about the project before its implementation?
Have you observed any positive influence of the day-to-day life in your community after the implementation of the project?
In what ways has the project contributed to improving access to electricity and introducing technological benefits within your community?
How can you affirm that this project has improved the quality of life for community members?
Were community members actively involved in the planning or implementation of the project?
Has the project led to any employment or skill development opportunities for individuals within the community?
How do you see these opportunities contributing to the long-term sustainable development and empowerment of community members?
From your perspective, how has the project taken into account environmental and social considerations in the design and implementation?
Have there been noticeable improvements in social well-being as a result of the project?
Would you recommend the implementation of this type of projects in other community with limited access to the energy network?

III. RESULTS

At the very beginning of the first semester, MEL students must take the Research Seminar, where they come up with the planning for the final project. They must pick if they are going to develop it individually or in pairs. Additionally, they must decide whether to write a project report or a research paper. After approving the seminar, they must develop the project using the knowledge learned in core courses. Students simulate and implement the project in the rest of the academic year. Finally, they will be awarded the diploma of Master of Science in Electrical Engineering after the dissertation.

The final projects are aligned to research lines previously stipulated by the university. The projects have been developed under the guidance of professors from different UPS research groups, such as the Science, Manufacturing, Advancements, and RegulaTion of TECHnologies research group (SMART-TECH). Typically, this group works on projects from different areas of engineering; nevertheless, some projects have focused on the use of technology for the sustainable development of small communities.

By the time this manuscript is written, there have been four registration years of the program, with 105 students in total, but only 80 effectively graduated. The final projects completed and approved sum up a total of 61. Table 3 presents a summary of the number of students in the program, as well as the number of final projects completed, by year of entry.

TABLE III
STUDENTS AND PROJECTS COMPLETED ORGANIZED BY YEAR OF ENTRY. SOURCE: THE AUTHORS.

YEAR	2018	2019	2020	2021	2022	TOTAL
Registered students	36	21	25	13	10	105
Graduated students	35	21	14	10	NA	80
Approved projects	28	18	8	7	NA	61
Individual projects	21	15	2	4	NA	42
Projects in pairs	7	3	6	3	NA	19

The first data allow to recognize that over the five academic terms of the program, a noticeable decremental trend is observed in both the number of registered students and the approval of final projects, thereby the subsequent low rate of graduated students. Such declines must raise concerns about the overall engagement and commitment of students in successfully concluding their academic journeys. Future research could intend to identify the various factors that contribute to this trend, such as shifts in student priorities, or potential challenges in the project approval process.

TABLE IV
NUMBER OF LOCAL SUSTAINABLE DEVELOPMENT PROJECTS ORGANIZED BY CLASS YEAR. SOURCE: THE AUTHORS.

YEAR OF	2021	2022	2023	TOTAL
Projects promoting sustainable development in local communities	4	8	5	17
Projects focused on other topics of electrical engineering	21	18	5	44
Total of final projects	25	26	10	61

Since the year 2021, three class years have successfully concluded. As this paper intends to understand the MEL's contribution to the improvement of less-favored areas of Ecuador through the execution of final projects, they are arranged into two big groups: the ones promoting the sustainable development of local communities, and the rest, that focus on other topics of electrical engineering. Table 4 classifies this data by year.

Thus, only 17 projects have become part of the study. All the projects are linked to RE because it is a straightforward way to contribute to sustainable development from the electrical engineering perspective. No project only related to CE has been proposed due to the need for agreements with electrical companies and energy regulators. It is reasonable to see that there is no project focused only on SI, LB or CP since the nature of the master's program. A classification of the number of projects per dimension is shown in figure 1.

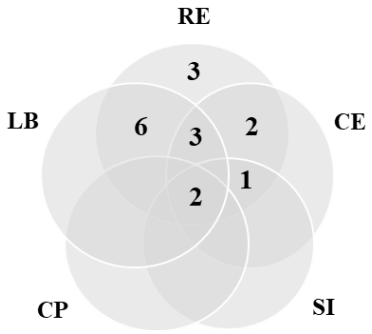

Fig. 1 Grouping the final projects based on the five dimensions under study. Source: The authors.

Since any project is allowed to be part of one or more dimensions at the same time, it is reasonable to explain this via examples. First, an active solar building heating system used for the reduction of electrical energy consumption falls into the RE and LB dimensions. In another case, a solar photovoltaic project for the electrification of a primary school located in an isolated vulnerable community, where the students will have free access to computers and internet, might comprise the five dimensions. Table 5 compiles the projects regarding the five dimensions, no matter if two or more are considered in the same project, per class year.

TABLE V
PROJECTS RESPONDING TO EACH DIMENSION INDEPENDENTLY ORGANIZED BY CLASS YEAR. SOURCE: THE AUTHORS.

YEAR OF	2021	2022	2023	TOTAL
Renewable energy	4	8	5	17
Electrification of less favored communities	3	4	1	8
Reduction of social inequalities	1	2	0	3
Local economic benefits	3	6	2	11
Community participation	1	1	0	2

As well, in order to understand how the student's preference for local sustainable development projects have evolved during the three years of graduated students, a tendency graph that depicts the number of approved projects versus the percentage of them regarding the topic under study is presented in figure 2.

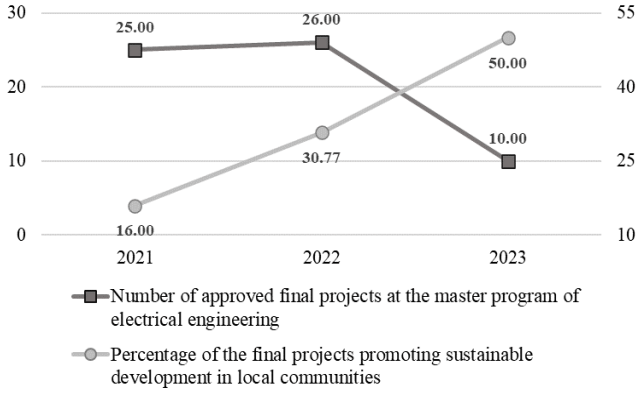

Fig. 2 Student's trend for local sustainable development projects. Source: The authors.

Figure 2 demonstrates that students of the master program in electrical engineering have been increasingly choosing final projects regarding local sustainable development, even closing the year 2023 with half of the projects related to this subject. Nonetheless, to keep this trend, Professors of the master's program should continue motivating students to explore innovative opportunities regarding this topic.

It is capital to encourage master's students to leverage their electrical engineering expertise to address real-world challenges faced by less-favored areas. Projects should focus on the efficient exploitation of renewable energy sources, or the integration of unserved regions into the national power grid, always embracing interdisciplinary collaboration, drawing on insights from environmental science, sociology, and economics, to create holistic solutions. Incorporating sustainable practices into final projects allows to make a positive impact on the well-being of communities through technology.

Moving on to the interviews and focus groups, the questions prepared for the staff of the electrical companies address topics like the contribution of the project to the production of renewable energy, production costs, and sustainability of the project over time. The respondents stated in a general way that the project came to the communities spontaneously, despite the different requests the members made to the electricity company to connect their localities to the national energy network.

In general, electricity company engineers are likely to support the implementation of renewable energy systems in local communities to generate electricity, provided its practicality. However, they expressed their concerns, such as:

"The reliability of this kind of systems must be carefully evaluated, and it is necessary to consider the regulatory and legal requirements for the installation."

"It is mandatory to ensure compliance with local regulations regarding the use of renewable energy sources, it includes permit obtainment and approvals from local authorities."

They have also indicated that the electrical energy generated in the community, majorly obtained through solar panels, only supplies the focused small communities. Although it still does not satisfy the demand for a high level of development of the communities, it has certainly influenced it on some level, and has improved somehow the quality of life of the inhabitants.

Electricity companies and regulator managers show mixed opinions about the installation of renewable energy by the UPS because these systems are not connected to the electricity network they manage. While the increased adoption of renewables can benefit the environment and promote sustainable development, it will impact the revenue and operations of the electricity company. Some of their positive and not much positive responses are:

"This is an opportunity to promote renewable energy and support sustainable development in local communities."

"It will reduce the demand for electricity from the grid, which can help reduce carbon emissions and environmental impact."

"During peak periods, the reliability and stability of the grid might be improved."

"As more consumers adopt this kind of energy, the demand for electricity from the grid may decrease, resulting in a decrease in revenue for the electricity company."

"Lower incomes may impact the ability of the company to maintain and upgrade the electricity infrastructure, which can ultimately impact the reliability and stability of the grid."

"It may be necessary to invest in new technologies and infrastructure to manage the fluctuation of clean energy generation, such as solar, and ensure the stability and reliability of the grid."

The interviews and focus groups carried out to primary beneficiaries served to better understand their experiences and how the implementation of the projects, such as the use of renewable energies and the automation of micro-grids, has allowed their communities to reach some goals related to local development. Regarding the characterization of rural communities, it includes a dispersed population, high dependence on a declining agricultural sector, a high unemployment rate, and an aging population.

"Before we spent hardships and sorrows without light, we slept very early, at approximately 7:30 p.m. Now, there is a lot of organization in our community, and we can arrange diverse activities that were not able to in past times".

"We already count three villages that have electricity. And we are starting to ask the UPS to work together on creating another project so that one more neighboring village gains access to electricity."

Testimonials like these are representative of the interviews with the beneficiaries of the project. Although most have great expectations about the installation of photovoltaic panels and other types of renewable generation in the community, some were somewhat skeptical about these changes due to the durability and sustainability of the energy production, and their worry about delays in connecting the community to the national energy network as retaliation from the electricity company. In the end, with great expectations they received the installation of the renewables in their localities, and they did not fail to express their satisfaction with the projects, such was the case that they are managing how to support other communities.

In most of the cases, benefited families remarked on the advantages that these projects have brought to them, especially the housewives, who expressed that life has completely changed for them. They mentioned that before the installation of the clean energy generating systems, there was not any access to refrigeration, making it impossible to preserve food. They also indicated that meal cooking was done by burning firewood and now they use small induction stoves. In both cases, the lack of refrigeration and firewood cooking caused several health problems, mainly digestive and respiratory diseases.

Likewise, they spoke about the importance of electricity in the education of children. During the pandemic, they missed many classes due to the lack of electricity, in spite of the donation of tablets by local and national governments. Two interviewees stated:

"The children were not able to connect to virtual classes because of the absence of electricity to charge their cellphone."

"It was impossible to get into the virtual platform to check homework and download the student material."

A reduced group of community residents mentioned the creation of micro-entrepreneurships after the introduction of electricity, including minimarkets, small appliance stores, craftsmanship, like electricians or electric tool operators, and handcraftsmanship, like artisans. The introduction of renewable energy systems has the potential to create job opportunities and promote economic development in the local communities of

Ecuador. The installation, maintenance, and operation of the systems require skilled labor, resulting in the creation of jobs for the local population.

Additionally, respondents explained that some community members were trained to be responsible for the panels, i.e., they were taught how to control and manage the systems, as well as how to give maintenance to the microgrid, thus avoiding tertiary costs. Likewise, the entire communities have explained the limitations of energy production, and how they should organize and manage the consumption of electricity.

IV. Conclusion

This manuscript presents a qualitative study that has been conducted to identify if the final projects of the four class years of the MEL at UPS have been able to become a factor for sustainable local development, mainly in vulnerable areas of Ecuador. The results have indicated that slightly more than a quarter of the projects support the sustainable development of local communities. It demonstrates that master's final projects can play an important role in the sustainable progress of a nation. Results also showed that the majority aim for the design and implementation of clean energy generation, mostly solar photovoltaic systems, in isolated less-favored communities. One of the most significant benefits of solar photovoltaic systems in Ecuador is the potential to reduce the country's dependence on hydrocarbons. Ecuador is heavily reliant on imported fossil fuels, which contribute significantly to the country's carbon footprint. By adopting solar PV systems, local communities can reduce their requirement for imported fossil fuels, leading to a reduction in greenhouse gas emissions and promoting sustainable development.

Even though the process of installing renewable energy systems tends to be expensive, it makes clear the interest of several students to contribute to the national goal of exploiting renewables in a broader way [27]. Moreover, it is concluded that the tendency to take advantage of renewable energies is a great opportunity to overcome the electrification gap still present in Ecuador, which can be replicated in other developing countries. The importance of master's final projects that focus on local development proposed in engineering programs cannot be overstated. By demonstrating the feasibility and impact of certain solutions, successful projects can contribute to the formulation of local and national policies that support practices related to sustainable development. Nonetheless, policymakers must pass beneficial bills that strengthen the cooperation between public companies and private stakeholders to support the deployment of clean energy generation to improve local development. Master's final projects in the field of electrical engineering that focus on sustainable development in local communities are vital for producing graduates who can make meaningful contributions to society. These projects not only enhance technical skills but also instill a sense of responsibility and the importance of ethical and sustainable engineering practices.

Also, the experiences shared from the Electrical Engineering program at Universidad Politecnica Salesiana Guayaquil underscore the significant potential of master's final projects in fostering sustainable development within local communities. By integrating students from diverse science fields into multidisciplinary teams, universities can effectively address complex challenges faced by communities. Interdisciplinary collaboration, holistic problem-solving, community engagement, policy advocacy, and effective communication emerge as pivotal components in this approach. By leveraging a wide range of expertise and perspectives, universities not only enhance the quality and impact of projects but also prepare students for real-world scenarios where multidisciplinary teamwork is essential. As universities continue to embrace this approach, they can play a vital role in supporting local communities and advancing sustainable development agendas, ultimately contributing to positive socio-economic and environmental outcomes.

Furthermore, this paper provides valuable insights into the potential of master's final projects to drive sustainable development in local communities. It serves as a resource for enhancing the sustainability component in master's programs by identifying trends, motivating students, and enriching curricula with sustainable practices. Interdisciplinary collaboration and engagement with industry stakeholders are emphasized as key elements in developing holistic solutions with real-world impact. Additionally, advocating for supportive policies empowers students to drive systemic change at both local and global levels. Leveraging the recommendations from this paper, master's programs can reinforce their focus on sustainability, nurture a generation of engineers equipped to lead the transition towards a more sustainable future, and contribute positively to communities and the environment. Integrating sustainability principles across disciplines, emphasizing project-based learning, fostering partnerships with stakeholders, enhancing the curriculum, promoting research initiatives, incorporating community engagement, and offering professional development opportunities are key strategies for achieving these goals. By implementing these strategies, master's programs can play a vital role in advancing sustainability and resilience in communities and ecosystems.

To wrap up, it is important to acknowledge the limited scope of this paper, focusing solely on electrical engineering projects at one institution, may restrict the generalizability of findings to other disciplines or institutions. Additionally, the lack of long-term impact assessment and limited stakeholder perspectives highlight areas for improvement in future research endeavors. To address these limitations, future studies could explore cross-disciplinary comparisons, conduct longitudinal assessments, incorporate community feedback, analyze policy implications, and supplement qualitative insights with quantitative assessments. Embracing these recommendations can allow future studies to provide a more comprehensive understanding of the role of master's programs in promoting sustainable development and offer valuable insights for

enhancing the impact of academic initiatives on local communities.

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