The following publication K. W. K. Lo, S. C. F. Chan, G. Ngai, J. Kalenzi, P. Sindayehaba and I. Habiyaremye, "From Beneficiary to Community Leader: Capacity Building through a Renewable Energy Project in Rwanda," 2019 IEEE Global Humanitarian Technology Conference (GHTC), Seattle, WA, USA, 2019, pp. 1-7 is available at https://doi.org/10.1109/GHTC46095.2019.9033011.

From Beneficiary to Community Leader: Capacity Building through a Renewable Energy Project in Rwanda

Kenneth W.K. Lo[1], Stephen C.F. Chan[1], Grace Ngai[1,2], John Kalenzi[3], Phanuel Sindayehaba[3], Innocent Habiyaremye[3]

[1]*Office of Service-Learning,*[2]*Department of Computing*
The Hong Kong Polytechnic University
Hong Kong
{kenneth.wk.lo, stephen.c.chan, grace.ngai} @polyu.edu.hk

[3]*African Evangelistic Enterprise – Rwanda*
P.O. BOX 1435, Kigali,
Rwanda
{jkalenzi, psindayiheba, ihabiyaremye} @aeerwanda.ngo

***Abstract* — This paper describes a strategy to build community capacity to address the challenge of SDG#7 (Affordable and Clean Energy) through an international student service-learning programme. The Hong Kong Polytechnic University partnered with an NGO in Rwanda in a four-year collaborative effort to electrify a semi-rural village in Rwanda with solar power. For sustainability, we developed a three-tier capacity building model that combined efforts from university students (who provide the technical expertise), strengths and expertise of a partnering local NGO (who had previously developed a community support infrastructure in the form of strong self-help groups), and community commitment and support (who provide the manpower initially and subsequently acquired the technical capacity).**

Keywords—capacity building, electrification, partnership, informal training

I. Introduction

It is a well-demonstrated fact that engineering for the social good, or humanitarian technology, has much to offer to developing communities. This is especially true for communities which are not well-served by national-level utility infrastructures such as electricity, water supplies and sewage, as oftentimes, improvised, small-scale projects are needed to fill in the gap.

The engineering disciplines have been traditionally active in service-learning, and every year, thousands of students provide service to underserved communities, either through academic programmes such as EPICS [1], or extra-curricular activities such as Engineers without Borders [2]. These programmes do a lot to bring useful technologies and expertise to communities where such levels of equipment or expertise are unavailable or difficult to obtain.

One of the biggest challenges faced by these projects is that of sustainability, especially that related to maintenance. Even the most carefully-executed project will suffer from errors that are not apparent at the time but surface later on; even the best-implemented of installations will eventually wear out, break down, or require servicing. Providing for this sustainability is not only vital for the useful lifespan of the project, but also vital to community development and ownership. Unfortunately, time and resource constraints post many barriers to students' provision of sustained support to community projects.

In this paper, we report on a strategy for sustaining the impact of a continual service-learning project that addresses SDG#7 (Affordable and Clean Energy) through SDG#17 (Partnership for the Goals – Capacity Building) community empowerment, and an evaluation of its outcomes.

II. Project Background and Community Needs

The Hong Kong Polytechnic University has a long-established culture of organizing service-learning programmes in local and overseas communities, especially in the area of engineering-related projects. Since 2005, our faculties and students have conducted over 100 engineering service-learning projects in Hong Kong, China, Cambodia, Vietnam, Myanmar, Indonesia and Rwanda. In 2012, service-learning was made a mandatory, credit-bearing requirement at the university. Since then, increasing numbers of projects have been established with NGOs, schools, community centers or other organizations.

Since 2013, we have partnered with African Evangelistic Enterprise Rwanda (AEE) to conduct service projects in Rwanda. AEE operates a range of community transformation and socio-economic development initiatives to build up the local capacity for self-sustenance. One of their key strategies is the self-help group, an assets-based approach that focuses on people's strengths rather than neediness. The goal is to strengthen civil society and enable individual members to assume responsibility and independence for their own lives. This philosophy works well with our own spirit of reciprocity [3], which stresses that service-learning projects must bring solid, tangible benefits for the community at the same time as fostering a learning environment for our students. We see community capacity building and fostering independence as one of the most impactful benefits that we can bring to a community, and thus, many of our projects work for 5 years or longer with the same community and NGO. This is particularly challenging but important for international projects, often taking place in developing countries where high-quality and formal education is not always accessible, where much of the learning still relies on practical, vocational or informal training which stresses practical learning through hands-on experience rather than conceptual learning from scholarly books.

Devastated by a genocide in the early 1990s, Rwanda was until recently considered one of the poorest countries in sub-saharan Africa. Even though economic growth and expansion has been high for several years recently, and electrification is speeding up, a very large portion of the population is still desperately poor, with an average GDP per capita of US$743 in 2017 **Error! Reference source not found.**. A sizable fraction of their population – up to 77% of households as of 2015 [5] – do not have access to public electricity, and suffers from what is called *electricity* or *energy poverty* [6][7].

III. Project Design and Evolution

Our solar energy projects started in 2015, with the objective to provide a reliable and low-cost power supply to rural communities in Gasabo District in Kigali Province, Rwanda. Even though the community is only 20 kilometers away from the capital city, the hilly terrain, (relatively) infertile soil and lack of irrigation kept agricultural productivity low. Poor roads and lack of funds for transportation isolates the community from the outside world. As a result, practically all of the population in this area is too poor even to afford improvised electrical setups (such as car batteries) commonly used in other developing communities to compensate for poor national infrastructure. The households rely on candles or kerosene to provide light, and some cannot even afford to purchase even these basic materials. The lack of electricity, in turn, makes television and even radio a luxury, further isolating the rural communities from the cities. The rural communities are trapped in a vicious cycle from which it is very difficult to escape. Many young people, upon finishing secondary school, cannot find a job in the city and find themselves stuck in the village farming as their parents did, but the shortage of large farmable plots makes it hard to advance beyond subsistence farming. Their isolation is such that they have no way to find out whether and when jobs are available, making them frustrated without a way out.

Technically, there are two aspects to our project. First, the community needs a source of power. Given the plentiful sunshine year-round in Rwanda, solar energy is a natural choice, and we use solar panels to turn that sunshine into electricity. Two models were applied, an individual household-based model and a community model.

TABLE I. PROJECT SCALE AND EVOLUTION

	2015	2016	2017	2018
Model	Individual Household-based	Community-based		
Project Team Size	24	13	17	20
Households Served	44	60	110	135
Power Generation	44 solar panel sets (40W)	4 charging stations (240W)	4 charging stations (240W)	5 charging stations (240W)

Both models used 20W solar panels and 14Ah solar battery as the basis. With a different number of panels installed, a varied output of the systems was customized for the situation. The major difference between these two models is the way of charging solar batteries. For the individual household-based model, the battery was connected to the 40W panel permanently, and each house owned a full system. For the community model, a 240W charging station would be installed to provide charging services to nearby households. Second, we provide them with a means to use this power. This includes wiring up household electrical infrastructure with a simple system including low-consumption LED lights (one 12W LED and two 5W LED), a 2A USB charger for cell phones and a rechargeable radio.

The non-technical aspect of our project directly links to capacity building and is arguably the key for long-term sustainability of projects that cross international borders. This involves the transfer of knowledge and know-how, both to the NGO partner, and to the community.

Table 1 shows the evolution of our project from 2015 to 2018. The most obvious detail evident from this table is the increase in the number of households served during the project, despite the small number of students involved in the project. This increased impact in the community was made possible by the change from a household-based model for the power generation, to a community-based model, as illustrated in Figure 1.

The household-based model was designed to best address the objectives of the first project in 2015, which targeted the poorest households in the community. It follows the conventional paradigm found in much of the developed world – each household installs its own 40W solar panels setup, usually on the roof, which is directly connected to a 10A PMW controller and a 14Ah solar battery to powers the household's appliances. Due to concerns about theft and the flimsy construction of some of the houses, it was decided to use a portable design for the solar panels. PVC water pipes were used to construct a foldable frame to which two 20W panels were attached (Figure 1). The household was then wired with a controller, battery, LED lights and a USB charger for mobile phone charging. An electrical plug and socket were installed to enable the solar panel to connect to the controller, and the foldable design ensured that the set could be brought out when needed and locked up otherwise.

Fig. 1. The original (2015) Household-Based Solar System. Panels are attached to a frame of PVC pipes to create a foldable, movable structure (Left). The panels are brought out for charging when necessary (Right)

The community-based model was developed through discussions with the NGO partner and community members during the post-project assessment period in late 2015. Feedback responses gathered from the community indicated that (1) due to the low consumption of the electrical devices, it was not necessary to charge the battery every day, hence there was "down time" and inefficient utilization of the solar panels; (2) beneficiary households expressed discomfort that their neighbors had not benefitted from the project; and (3) the NGO evaluated that they were confident that they could provide adequate on-site and follow-up support for a larger-scale implementation.

This modified model builds on not only the communal, sharing culture common in rural communities, but also encouraged through the self-help group model very successfully promoted by our NGO partner. This approach steps away from the individual household-based model and moves towards a community model. The NGO helped us to identify households "of reputation" in the community, who would act as "hosts" for solar "charging stations". In essence, this meant that the identified household would contribute one room that would be wired up as a charging room, where community members could plug in their batteries to be charged.

Fig. 2. A charging station being installed (up), and the interior charging room (down). The panels are permanently attached to six controllers. Community members bring their depleted batteries and plug them in for charging.

Technically, a set of 12 solar panels (240W) would be installed permanently at the host's house, and the panels connected to 6 individual 20A PMW controllers. The host would have the responsibility of maintaining the security of the system and the commitment of making it available for the community's use. In return, the host's home would be wired directly to the solar panel system, thus ensuring a constant supply of electricity. Therefore, the remaining 5 controllers can provide charging services to nearby families. The hope was that this would raise the utilization efficiency of the solar panels, since they would be charging more batteries more often, ideally continuously through the day. There would be an added inconvenience to the non-host households since they would need to carry their batteries to the host for charging. But the evaluation with our NGO partner indicated that this was an acceptable price that they were willing to pay for access to electricity.

The immediate benefit of this new approach was a massive increase in the number of households that could be served by the project. Since the cost (purchase and transportation) of the electrical appliances were much smaller compared with the panels, this allowed the project to impact many more households, with only an incremental increase in cost. In terms of implementation, this shifted the focus from identifying households that were the most in need, to a village-based model, where the objective was to blanket as many households as possible (and who were willing) during the duration of the project. This also necessitated a new model for sustainability, which we will describe in the next section.

IV. Sustainability and Capacity Building

The change to a community-based model for our project created two challenges as well as opportunities:

1. There would be increased time pressure on the team. The installation of the charging station would be quite complex, involving multiple panels connected to multiple controllers, and a more elaborate setup to ensure safety and reliability. However, at the same time, more households needed to be wired up with their own electrical system and appliances. Even though installing household wiring was a much less complex task when compared to installing the charging station system, manpower would still be needed.
2. Expanding the beneficiaries to more people will logically translate to an increased need for repair and support, as more systems installed will mean more usage, and more breakage. Under the household-based model, we worked together with the family to install the system, simultaneously training them how to maintain and conduct small repairs. The increased time pressure under the community-based model, however, made this impossible.

Our discussions with the NGO, and our previous experiences with similar projects [8][9] suggested that capacity building *within the community* might be a potential solution. A major challenge, however, is the level of education of the community. Due to poverty, most of the community residents do not have a high level of education, which makes theoretical or conceptual learning is a challenge.

A tripartite capacity building model was developed to address these challenges. Figure 3 shows this model, the various stakeholders and their roles and missions. The model involves a **project team** of multidisciplinary members, a **bridging team** from the frontline NGO partner and/or local university and a **community team** of community residents.

The project team of teachers and students are participating in a service-learning project. The teachers are the primary designers of the project, in collaboration with the bridging team partner

NGO (to be mentioned later). The students' primary objective is to learn from and through service to the community. Our project design takes a multidisciplinary team approach to engineering projects [10], which enriches engineering projects with complementary skills such as community assessment and also empowers non-engineers to understand the impacts, challenges and barriers behind engineering projects.

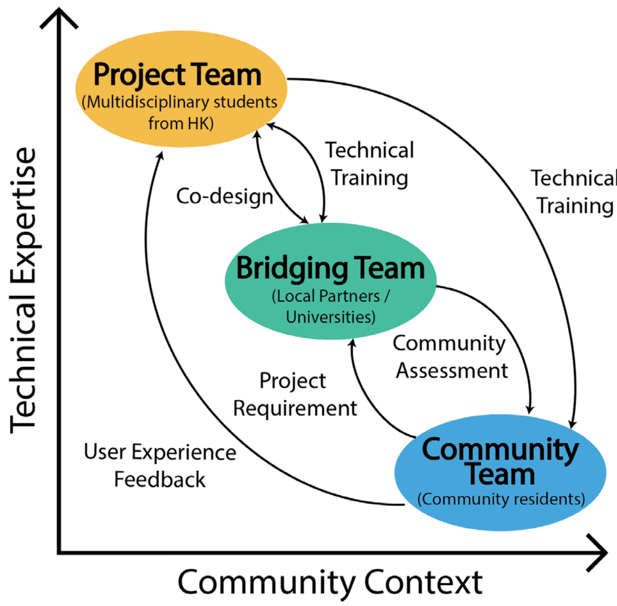

Fig. 3. Capacity Building Model

The bridging team consists of individuals who are local to the culture and context, though not necessarily to the community. The NGO partner, who has the necessary expertise and experience to make judgements on community needs and assets, identifies the community and negotiates with community stakeholders to form agreements for thoughtful community engagement, i.e. entering, building and exiting the community. Since their core business is to serve the community, usually the same one in which the project is held, they have an interest in maintaining bonds and relationships, both between them and the community, as well as within the community itself. Also, spare equipment and tools would be stored in the NGO partner in case of any replacement.

Another component of the bridging team is student volunteers from the local universities, who usually join the project out of curiosity, either about the project itself, or about the incoming team, and a desire to help their fellow countrymen. Since they are fellow university students, they serve as peer guides to the students on the project team and translate the project team students' engagement into the local culture and context.

The community team comprises of community residents. They are the people who will be most impacted by the outcome of the project. For sustainability purposes, their empowerment can be seen as *the* critical ingredient for success, but also, because of the disparity in education, the most difficult to ensure.

Together with the bridging NGO, the project team teachers designed a certificate-bearing learning program for the young people in the community. The NGO then promoted this learning program to the community and enrolled a group of young people. The requirements for enrollment were that the enrollees had to (1) have some level of formal education (i.e. be able to read and write in their native language), and (2) have a reputation for commitment, integrity and responsibility in the community.

The learning program that we devised in the Rwanda context is a just-in-time, learning-by-doing model that resembles the "industrial training" modules mandatory for engineering students in Hong Kong. The community team youth work alongside the project and bridging team of university students to carry out and implement the project. Hence, the project essentially serves as a practical learning program. A roster is kept, and attendance monitored, and well-performing members recognized with certificates at the close of the project.

V. Implementation and Observations

Table 2 shows the evolution of the project teams since the first-year household-based project in 2015. It can be seen that the ratio of non-engineering to engineering students in the project team has grown, along with the size of the community team and the number of university students in the bridging team has been growing steadily since the first year, while the number of NGO staff involved in the bridging team has dropped. This is by design. In the early days of the program, both the teachers in the project team and the NGO partner were not certain about the operation and implementation of the project. To ensure success, the decision was made to minimize uncertainty by selecting students who had a more relevant background, and to rely more heavily on the staff of the NGO, who were familiar both with the community as well as working with outside partners. As the project team and the NGO gained more experience, it was then possible to incorporate more non-engineering students, which brings the composition of the project team closer to the demographics of the university, and also allows more students to benefit from this unique learning experience. This added experience also encouraged the project team and the NGO to expand the bridging team to include local university students, who can better relate to the project team students as peers and could alleviate the workload of the NGO. Finally, as the project continued in the same community over multiple years, the community team was also expanded to incorporate new members.

TABLE II. Change in Team Members and Size from 2015 to 2018

		2015	2016	2017	2018
Project Team	**Teachers**	4	3	4	3
	Engineering Students	9	4	5	5
	Non-Engineering Students	7	6	8	11
Bridging Team	**University Students**	-	-	7	8
	NGO Staff	6	3	1	1
Community Team	**Village Residents**	8	10	13	15

The preparation stage starts in Hong Kong, approximately six months before the actual project implementation in Rwanda. The project team undergoes a series of about 36 hours of structured and rigorous training in the form of lectures, seminars, discussion groups and technical workshops. This equips students with the necessary background (historical and cultural) knowledge, technical skills, and hands-on experience. As some of the students were not from engineering disciplines and did not have any prior science background, problem-based teaching [11] was used to illustrate abstract concepts, such as voltage, current, series and parallel connections, in a concrete way through experimenting with real circuits and real connections.

TABLE III. TRAINING SCHEDULE

		Project Team	Bridging Team	Community Team
Hong Kong	e-Learning, Lectures & Case Studies (16 hrs)	√		
	Technical Training Workshops (30 hrs)	√		
Rwanda	Orientation (3 hrs)	√	√	
	Intensive Training & Preparation (8 hrs)	√	√	
	On-site Implementation (50-60 hrs)	√	√	√

The project starts once the project team arrives in Rwanda, and the second phase of training put into motion with the bridging team. The team spent about 8 hours in testing and training to finalize the design, assemble the solar system, lights, etc. and test all the deliverables. This on-site training allowed the project team students to transfer their knowledge and skills to the bridging team.

Finally, the training was followed by the project in which the deliverables were deployed. During the project, the project and bridging teams worked with the community team to install the system. Through teaching by demonstration, team members were able to master the technical skills, and some of them were able to help maintain the equipment in the long run.

Since 2015, this project has successfully wired up an entire village of almost 350 households in Kigali province. Per-household, the amount of electricity is perhaps not large – a single charging station of 240W serves around 30-50 households – but even this small amount of electricity has made its impact. The LED lights – even though there are only 3-4 per household – enable the family to extend its working hours for household work, such as for study, fellowship, and visiting. The capacity for mobile phone charging makes it unnecessary for the villagers to walk long distances, often over 2 hours to charge the phones. A small rechargeable radio, which we added after in 2017, provides news and entertainment, and a connection to the outside world. One family told us that since the light was installed at their home, their children's schoolmates from neighboring villages often come to study on the weekends, which appears to have positively impacted their children's school performance. Another family told us that they now no longer need to send their children to bring the mobile phone for charging at the village center, thus their children can go to school on time (they previously used to bring the mobile phone for charging twice a week before school).

Interestingly, the combination of students from Hong Kong, Rwanda and the community has brought about some interesting co-design solutions. Figure 4 shows an example. Many households in Rwanda villages comprise of a collection of small huts, which are used for different purposes, all of which need light, but usually not at the same time. Faced with the problem of a limited number of lights that needed to serve multiple huts, the students from the project and bridging teams worked together with community youths to devise an interesting design that involved a movable lamp at the end of a long coil of wire, that could be placed around the compound when necessary. This illustrates the co-design process in which the groups of students work together to evaluate the current situation, review the solutions, compare the actual and desired condition for the purpose of prioritizing concerns, and modify the solution to be culturally responsive.

In addition, some indirect benefits have also been observed. The most obvious indirect beneficiaries have been the young people from community team. Some of them have been involved in the project since its inception. This experience has enabled them to build up their skills, to the point where some of them are able to execute the project on their own.

Fig. 4. A Bridging Team member designed a movable light that allows use in both indoor and outdoor contexts (Left) & Members from bridging team and community team conduct a briefing to household members on the operation of the system (Right)

A particularly encouraging example is the family of one of the young people who had been involved in the community team. Their house had been wired during the project, but shortly afterwards, the family built a new house. Using the tools that we had given them for repairs, they successfully dismantled the entire electrical system from the old house and installed it in their new house. An inspection by the project team teachers showed a good quality of wiring, with properly-secured wires and secure connections. The young person said:

"We thank you for your training ... I installed it [the system] myself in a new house near the road."

Our NGO partner's field observations corroborate the fact that the community team participants appear to have absorbed the skills and are able to practice them independently. It also appears that their expertise is recognized by the community:

"the community young people trained provided first hand help such as replace some wires, lighting lamps replacement…or when the controllers are properly connected."

On average, it appears that the young people were asked to provide help for their neighbors twice a quarter:

"Trained young people were still helping the villagers, for example, the mouse cut the wires and sometimes it required replacing wire, or the battery did not charge, they did maintenance and repaired depending on the nature of the case/ issue raised."

For some of the young people, their skills appear to have matured beyond basic repairs. When one of the solar charging stations was struck by lightning in early 2018, the young people were called upon to repair it. The complexity of the system, involving a parallel circuit with multiple controllers, meant that they could not execute a full repair, but an inspection by the project team the following summer found the station functional, if inefficient – the young people had directed the wires directly into the batteries, bypassing the controllers. This indicates a level of comfort and internalization of knowledge that we had not expected.

The capacity of the NGO itself has also expanded. Prior to 2015, their poverty alleviation efforts had mostly revolved around agriculture, health, education and financial management, mostly targeting women and children. To support the solar power project, it was necessary to expand their target demographic to include young people, and a self-help group was set up for this purpose. In early 2019, the NGO successfully referred two of the young people to another organization to work in a solar energy project in another province.

VI. Discussion

Engineering-based projects undoubtedly have much potential to bring positive impacts to underserved communities, by bringing in know-how and equipment that may not be readily available in the target community. For the purposes of sustainability, however, it is important to also bear the community aspect in mind. In a way, this is more challenging than the technical aspect, as it involves more unpredictable and fluid factors.

Our experience working in various engineering-based projects in developing regions [12] suggests that several ingredients are necessary for this to happen:

1. Work for the long-term. Engineering projects, by nature, usually require specialized expertise to set up and maintain, as well as resources, labor or space on the part of the community or NGO. This often requires support beyond the duration of the project, or longer-term investments from the community, which is best supported through a long-term working relationship.

   In our case, the project was co-designed with the NGO partner as the result of a long-term collaboration and mutual understanding. Our projects in Rwanda, with the same NGO partner, began in 2013, two years before the inception solar panel project. Initially, our projects involved installing and teaching Computer and Internet Literacy. We learned from the NGO partner that there were many schools in rural and even semi-rural areas that did not have electricity, without which they could not run computers. In 2014, we installed solar panels and computer networks at two primary schools. This process enabled the NGO to learn about our expertise and capacity, and also enabled us to learn about the NGO's core strengths and stature in the community. The first solar project in 2015 was a co-designed project, to address the more critical needs in the community. However, this would not have been possible without the process of learning about each other, and understanding the capacities, needs, will and commitment of all parties involved.

2. Train the community as well as the supporting partners. In many of these projects, the NGO partner is the primary liaison between the project team, thus it is natural to provide training for them. However, as the community members are the frontline stakeholders who will be living with the installation on a day-to-day basis, it is also critical to provide training for them, even though language and other issues may make this a more challenging task. From a capacity building standpoint, since the community members are usually the underserved ones, training for them has the potential to effect larger changes in their livelihoods.

3. Design the project to leverage upon the strengths of the NGO partner. In our case, our NGO partner had very strong ties into the community and a well-established track record in facilitating and supporting self-help groups. We therefore designed our project to leverage upon the existing strengths: the initial households in the inaugural project were self-help group members, and the community team has transformed into a loose self-help group of its own. When we first recruited the community team for the 2016 project, a few of the young people on the team did wire their own house as part of the project, but most of them joined for the sake of learning a skill. As time went on, and more houses were wired, the community team members would often be wiring other people's houses before their own was scheduled to be wired, and without knowing when, or if, their house would be scheduled. (Some of their houses were not scheduled for wiring until the 2018 project, which succeeded in electrifying the entire village.) This spirit of "moving beyond the beneficiary" is the spirit that we hoped to build in the community team, and many of young people in the initial team recruited in 2016 have come back year after year. As they progress in their experience and skills, they take on the task of mentoring other young people who join later.

VII. Conclusion and Future Work

In this paper, we describe a multi-year project that aims to electrify a rural village in Rwanda through service-learning projects. To date, the project has successfully electrifying an entire village of over 300 families.

The success of this project depended and benefitted significantly from a long-term collaboration. In the process of designing, revising and executing the project, the university project team, the NGO bridging team, and the community team built up trust and respect for each other, and all sides grew in experience, confidence and capacity. This is demonstrated in the growth in the number of households served per project, both in absolute terms and as a function of the size of the project team.

This project has also developed a stable base from which we can expand our impact to other dimensions of quality of life besides electricity. In 2019, two additional teams are anticipated to join the project in Rwanda: tackling SDG#2 (Zero Hunger) and SDG#15 (Life on Land) through a kitchen garden and a fuel conservation project.

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