Integrating Sustainability, Technical Skills, and Cultural Competencies: Educational Insights from a Volunteer-Led Off-Grid PV Project in Peru

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Abstract

This paper presents a case study of a volunteer-led off-grid photovoltaic (PV) system installation for a remote Peruvian community. Conducted in collaboration with the local host organization, Light Up the World (LUTW), the project encompassed the design, installation, and commissioning of a standalone solar energy system. While these technical objectives were central, the field trip also served as a platform for experiential learning, fostering personal growth, social awareness, and the development of intercultural competencies. Volunteer participants reported a deep appreciation for Peru and its people, enhanced understanding of energy and development challenges, improved cross-cultural communication, and strengthened sense of self. These outcomes highlight the dual impact of volunteer-based sustainable development initiatives—benefiting both the communities served and the volunteers themselves.

Keywords: Off-grid photovoltaic systems, sustainable development, energy education, cultural competency, volunteering, rural electrification.

1. Introduction

Electricity is fundamental to the functioning of modern societies, directly influencing economic growth, public health, education, and overall quality of life. Although often overlooked in developed countries, the lack of electricity in many parts of the world has deep and far-reaching effects (Banerjee et al., 2021). It limits access to essential services, restricts economic opportunities, and perpetuates cycles of poverty and inequality. To address this global challenge, the United Nations established Sustainable Development Goal 7 (SDG 7) in 2015, aiming to ensure universal access to affordable, reliable, sustainable, and modern energy by 2030 (United Nations, 2015). SDG 7 recognizes energy as a key driver of progress across multiple sectors, including health, education, economic development, and climate action. Achieving this goal is critical for building resilient communities, reducing environmental impact, and fostering inclusive growth.

Although significant progress has been made since the adoption of SDG 7, recent years have seen a slowdown due to a combination of factors, including the COVID-19 pandemic, economic instability, and logistical challenges in reaching remote populations (IEA, IRENA, UNSD, World Bank, WHO, 2024). Global investment in energy access has not kept pace with population growth in underserved regions, and many rural areas remain disconnected from national grids. Energy poverty remains a major barrier in many regions, particularly in rural and remote areas where infrastructure is limited and the cost of extending energy services is high. These regions often face compounding challenges such as low incomes, limited institutional capacity, and rapid population growth.

While Sub-Saharan Africa is home to the majority of the world's energy-poor population, many remote communities in South America, particularly in the Andean highlands and the Amazon rainforest, also face significant energy poverty. These regions share common challenges such as geographic isolation, limited infrastructure, and socio-political barriers that hinder access to reliable electricity. In the Andes, rugged terrain and dispersed populations make traditional energy delivery costly and inefficient. Extending the national grid to these remote areas is often impractical due to geographic and economic constraints (Ramirez, 2016).

Off-grid photovoltaic (PV) systems and micro-grids offer a practical and sustainable solution to the challenges of rural electrification. By harnessing solar energy independently of centralized power grids, these technologies are particularly well-suited for remote regions with high solar potential. Peru's varied geography and abundant

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sunlight make it an ideal candidate for such systems (Ramirez, 2016). This potential has been increasingly recognized through government-led initiatives such as the Second Rural Electrification Project - RE2 (ESMAP, 2019), as well as through the efforts of international donors, private sector partners, and non-governmental organizations (Jensen, Hopps & Bryan, 2019). Together, these actors have significantly advanced the deployment of solar home systems across underserved areas.

As of 2023, Peru achieved a national electrification rate of 96.2%, with urban access at 99% and rural access at 85.1% (World Bank, 2023). However, these national figures mask significant regional disparities. Rural communities in the Andean North and the Amazon region continue to experience significantly lower electrification rates, largely due to geographic isolation and inadequate infrastructure. According to The Borgen Project (2025), over 30% of households in high-altitude rural areas of the Andes still lack access to electricity. Despite more than a decade of advocacy by some communities, progress has been limited, highlighting a persistent and deepening energy access crisis in the region.

Despite notable progress, off-grid solar energy projects in rural Peru, particularly in the Amazon and Andean regions, continue to face a complex array of persistent challenges that undermine their long-term sustainability. Financial constraints remain a significant barrier, limiting the reach of dissemination programs, and the absence of local infrastructure for marketing, servicing, and maintaining solar technologies further complicates adoption, making it difficult for rural residents to purchase, repair, or sustain these systems (Energypedia, 2023). Even when installations are successful, inadequate user training and insufficient post-project support often lead to underutilization or system failure. Equipment degradation and logistical difficulties in remote areas hinder timely repairs, while weak governance structures and unclear responsibilities for maintenance exacerbate these issues, leaving communities without the institutional support necessary to keep systems operational (Feron et al., 2017).

These challenges are especially pronounced in the most remote and marginalized communities, those that are geographically isolated, economically disadvantaged, and culturally distinct. While these populations stand to benefit the most from decentralized energy solutions, they remain the hardest to reach and the most underserved. Social and institutional shortcomings further complicate the picture: many projects are implemented without meaningful community involvement, resulting in poor alignment with local needs and a lack of ownership. Without culturally sensitive, community-driven approaches, even well-intentioned interventions risk failure. These intertwined barriers, economic, technical, institutional, and cultural, underscore the urgent need for innovative financing mechanisms, supportive policy frameworks, and inclusive strategies that respect local traditions and ecosystems (Feron et al., 2017; Moran et al., 2022).

2. Solar energy for change: LUTW - volunteer collaboration

Light Up the World (LUTW) is a Canadian non-profit organization leading the global fight against energy poverty through sustainable solar energy solutions. The organization's mission is grounded in the belief that access to energy is a catalyst for social equity, environmental sustainability, and economic development (LUTW.org, 2025).

LUTW's origins trace back to a pivotal innovation by founder Dr. Dave Irvine-Halliday, who in 1998 demonstrated that white LED lights could offer safe, affordable illumination for rural communities without electricity. This breakthrough led to the first village in Nepal being lit by solar-powered LEDs in 2000, with the model soon replicated in India and Sri Lanka. Since its inception, LUTW has reached more than one million families across 55 countries, significantly contributing to the global reduction in energy poverty. In 2010, the organization shifted its focus to Peru, where many Amazonian and Andean communities still lacked access to sustainable electricity. Over the ensuing 15 years, they have provided solar power to 94 remote communities, directly benefiting over 11,500 people (LUTW.org, 2025).

In Peru, Light Up the World (LUTW) has grown far beyond its original mission of providing basic solar lighting to remote last-mile communities. What began as a way to illuminate homes has evolved into a comprehensive strategy for rural development and education. Today, LUTW powers not only households but also community centers, small businesses, and schools, bringing internet access, tablets, and computers to some of the country's most remote areas (LUTW.org, 2025). Solar energy has become more than a power source for lighting; it's now a catalyst for educational equity. By enabling digital learning in underserved regions, LUTW helps advance Sustainable Development Goal 4: "Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all" (United Nations, 2015).

This progress is especially critical in areas like the Andean highlands, where education is often disrupted by distance, harsh weather, and limited infrastructure. Solar-powered digital classrooms provide consistent, high-quality learning and introduce students to digital literacy, an essential skill in today's world. Teachers gain access to professional development, and students are exposed to global perspectives. These classrooms also promote gender equity, as girls are more likely to attend school when environments are safe, well-lit, and equipped with modern tools. Additionally, digital learning supports community development by enabling adult education and expanding access to global knowledge (Rumbayan et al., 2025).

LUTW is driven by a deep commitment to community empowerment, sustainability, and inclusive engagement. Central to its approach is the training of local residents as solar technicians, which fosters technical capacity, promotes local ownership, and ensures the long-term viability of energy systems. This model demonstrates how innovative technology and grassroots participation can converge to create lasting change and illuminate a path toward a more equitable future (LUTW, 2025).

The success of LUTW's initiatives in remote Peruvian communities is made possible by a collaborative network of volunteers, donors, and corporate partners. These stakeholders are drawn to LUTW's transparent, community-driven approach and the tangible, life-changing outcomes it delivers. Their contributions, ranging from financial support and equipment donations to skilled labor and goodwill, enable LUTW to operate in some of the most energy-deprived regions. Together, they help light up homes, schools, and futures (LUTW, 2025).

Donors provide the consistent funding necessary to sustain and expand LUTW's projects, while corporate partners contribute both financially and through the provision of essential equipment such as solar panels and batteries. These resources make it possible to train local technicians, procure materials, and extend access to solar energy in areas where traditional infrastructure is not viable (LUTW, 2025).

Volunteers play a multifaceted role in LUTW's work. Beyond assisting with on-site installations, they contribute financially and facilitate the transfer of technical skills and labor. Their involvement fosters cross-cultural exchange and solidarity, reinforcing the social dimension of sustainable development. Volunteerism, while rooted in altruism, is also mutually beneficial. Volunteers gain technical and cultural competencies, improve teamwork and problem-solving skills, and develop a deeper understanding of global development challenges (Kelly, 2023).

Volunteer motivations are shaped by a blend of ethical responsibility, experiential learning, and the appeal of travel and challenge. For students, volunteering offers opportunities for personal growth, cultural immersion, and practical experience. Programs that align with these motivations, through thoughtful design, structured support, and recognition, are more likely to foster sustained engagement and long-term success (Sextus et al., 2024).

3. Ipipata case study

3.1 Project Overview

The Southern Alberta Institute of Technology (SAIT) Electrical Engineering Technology (EET) program has a longstanding collaboration with LUTW, through which they have successfully installed off-grid photovoltaic systems in five remote Andean communities. These immersive field trips not only advance LUTW's mission of expanding energy access but also provide SAIT student volunteers with invaluable hands-on experience in designing and installing off-grid PV systems (Persaud, 2024). Beyond technical training, the trips offer students a deeper understanding of the challenges faced by remote communities and the transformative impact of electricity, particularly in enhancing educational opportunities for children. The demanding, fast-paced nature of these high-altitude deployments also fosters personal growth, cultural awareness, and the development of intercultural competencies through unique social, recreational, and travel experiences.

In May 2024, a team of twelve SAIT Electrical Engineering Technology (EET) students, accompanied by two instructors, partnered with Light Up the World (LUTW) to implement an off-grid photovoltaic (PV) system in the mountain-top community of Ipi Pata, located in Peru's Huancavelica region. Home to approximately 90 residents, Ipi Pata sits at an elevation of 3,900 meters above sea level, surrounded by the rugged terrain of the central Andes. The community is very remote, with no direct paved road access, and all materials, including solar panels, batteries, tools, water and food supplies, had to be transported from the regional capital of Ayacucho.

Electricity pylons were observed a relatively short distance away in a nearby valley, but given the difficult terrain, the size of the community and its remoteness, it is expected to take a decade or more before such infrastructure reaches the community of Ipi Pata. There was also visible evidence of photovoltaic (PV) system knowledge within the community. The headmaster demonstrated familiarity with PV technology and used a small PV module to charge an automobile battery, which was used to power his laptop. One nearby residence also featured a small pole mounted PV module, indicating prior exposure and interest in solar energy solutions.

The installation site featured a modest educational and community complex composed of three primary structures arranged in a courtyard-style layout, as shown in Figure 1 below. At the center stands the main building, which functions as the primary school and serves as the heart of daily educational activities for local children. It is equipped with basic classroom furnishings and learning materials. Flanking the school, there are two smaller auxiliary buildings: one designated as a kitchen (lower right) and the other as a dining room (lower left). All three buildings are constructed using plastered adobe, a traditional, locally sourced material known for its thermal insulation properties, and topped with roofs made of plastic sheeting stretched over rough wooden beams.

The photovoltaic (PV) system was designed to meet the estimated daily energy needs of both the local school and the surrounding community. These estimates were informed by direct interviews with community members, focusing on typical usage patterns and affordability considerations. This participatory approach ensured the system was appropriately scaled to support educational activities while also addressing broader community requirements.

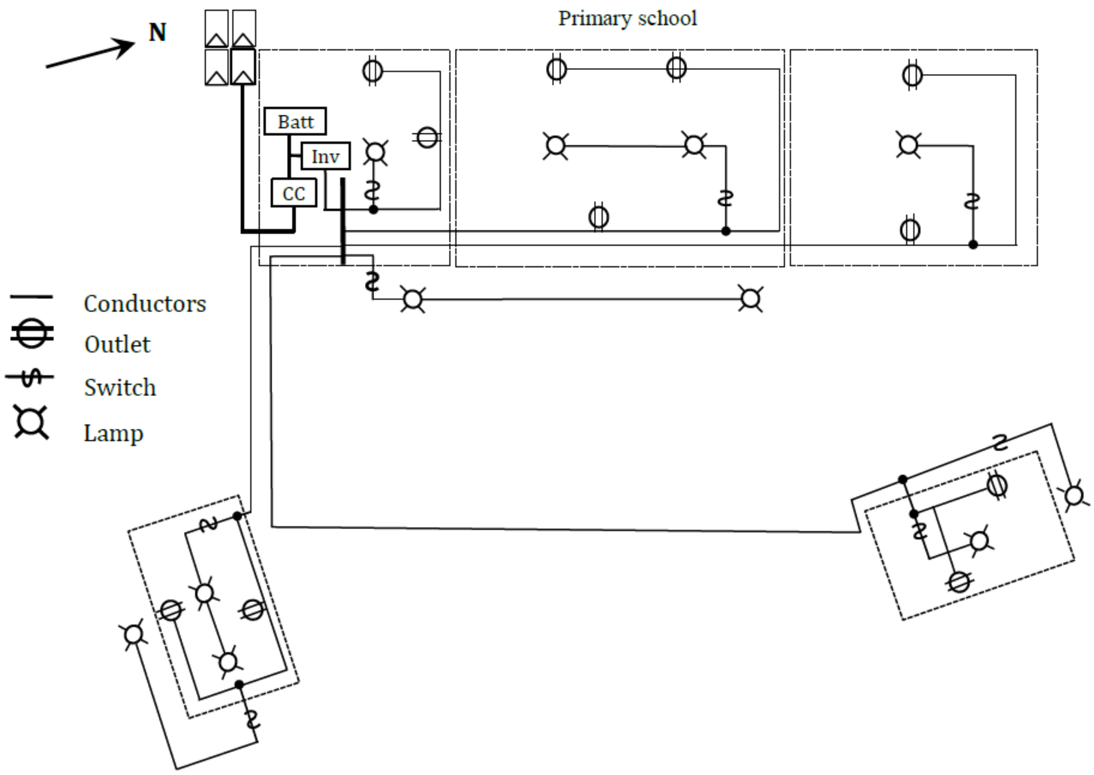

Figure 1: Site plan and wiring diagram (not to scale)

3.2 Site Characteristics

The installation site, Ipi Pata, is geographically located at latitude 13.0175°S and longitude 74.8032°W. The region offers favorable environmental conditions for solar energy generation with high year-round irradiance and cool temperatures (Weather Spark, 2025):

- Solar Irradiance: Average daily solar insolation is approximately 5.8 kWh/m²/day, with a 90th percentile range between 4.2 and 8.0 kWh/m²/day.
- Ambient Temperature: The average temperature is 10°C, with seasonal variations ranging from 0°C to 20°C.

3.3 Load analysis

As detailed in Table 1, the load profile includes 16 different devices with an average daily energy consumption of 2.75 kWh, a peak power demand of 3.3 kW and a surge load of 3.9 kW. Among the devices, the blender (600 W) and kettle (1,500 W) stand out due to their high power-ratings, despite being used only for short durations.

Table 1: PV system loads

Load	Quantity	P_{rated} (W)	P_{peak} (W)	P_{surge} (W)	Daily use (hr/dy)	Weekly use (Dy/wk)	Weekly energy (Wh/wk)	Avg daily energy (Wh/dy)
LED bulbs	22	16	352	352	1	7	2464	352.00
LED tubes	10	16	160	160	1	7	1120	160.00
Modem	1	10	10	10	8	5	400	57.14
Satellite	1	50	50	50	24	7	8400	1200.00
Smartphone	5	10	50	50	1	7	350	50.00
Speaker	1	30	30	30	2	2	120	17.14
Laptop	1	40	40	40	5	5	1000	142.86
Projector	1	300	300	300	1	5	1500	214.29
Blender	1	600	600	1200	0.1	7	420	60.00
TV/DVD	1	40	40	40	2	7	560	80.00
Radio	1	10	10	10	1	7	70	10.00
Kettle	1	1500	1500	1500	0.1	5	750	107.14
Computer	1	50	50	50	3	5	750	107.14
Printer	1	70	70	70	2	5	700	100.00
Tablets	4	10	40	40	2	5	400	57.14
Auxiliaries								35.00
Total AC	-	-	3302	3902	-	Total	19004	2749.86

3.4 System Components

Figure 2 shows a schematic of the installed PV system. It consists of the following major components:

- Photovoltaic Array: Four 370W modules arranged in a 2S2P configuration, yielding a total capacity of 1480 W. The PV array sits on a free-standing steel structure, and it is at 13° to match the site latitude and optimize all-year energy capture. The azimuth orientation is 10° east of true north, rather than true north, due to space restrictions.
- Battery Storage: One 48 V, 100 Ah lithium iron phosphate ($LiFePO_4$) battery with a nominal capacity of 4.8 kWh.
- Charge Controller: 150V|35A MPPT controller responsible for regulating the charging process.

- Inverters: A 3000VA, $48V_{DC}$-$230V_{AC}$ main inverter with a 6000 W surge rating. A second 350VA inverter is used to power electronics, maintain communications, and provide emergency ac power in the event of a main inverter trip.

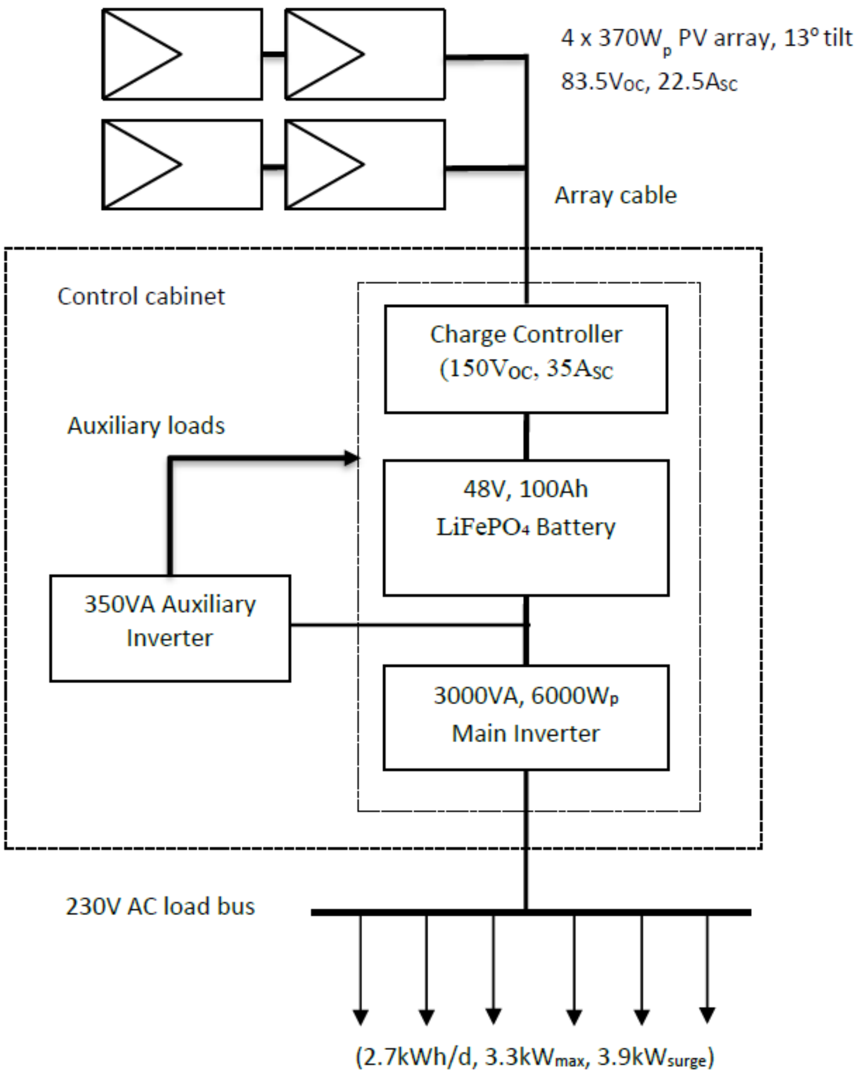

Figure 2: PV system overview

3.5 PV System Analysis

3.5.1 Energy Balance and Performance

The PV system was designed to meet the essential daily energy demands of the Ipi Pata community, offering reliable access and resilience against seasonal and daily solar irradiance variability. With a total array capacity of 1480 W and a daily load demand of approximately 2.75 kWh, the system provides a surplus generation capacity of around 3.65 kWh/day under typical conditions.

- Performance Ratio: 70% (array-to-load efficiency)
- Required Daily Insolation: 2.65 kWh/m²/day to maintain full battery charge
- Expected Insolation Range (90th Percentile): 4.2 to 8.0 kWh/m²/day
- System Output at 4.2 kWh/m²/day: 4.8 kWh/day

This surplus ensures uninterrupted operation even under worst-case solar conditions, with the system capable of sustaining essential loads for 1–2 days during low irradiance periods.

3.5.2 Battery Storage and Autonomy

The system includes a 48 V, 100 Ah lithium iron phosphate ($LiFePO_4$) battery with a nominal capacity of 4.8 kWh and a usable capacity of 4.1 kWh. With a round-trip efficiency exceeding 95% and an expected lifespan of 6000 cycles (~16.4 years), the battery supports overnight operation and mitigates shortfalls during low solar input or demand surges.

- Buffer Capacity: ~1.35 kWh (approx. 50% above daily load)
- Functionality: Ensures autonomy and operational continuity at minimal cost

3.5.3 Inverter and Load Management

The system uses a 3000 VA main inverter with a 6000 W surge rating, complemented by a secondary 350 VA inverter for critical electronics and emergency backup.

- Continuous Rating: 3000 VA
- Peak Load: 3.3 kW

The main inverter currently operates near its peak load capacity, necessitating staggered use of high-power appliances (e.g., kettle, blender) to avoid overload. Community education on load management is essential to optimize usage and prevent system interruptions. A future inverter upgrade would accommodate anticipated load growth and reduce reliance on demand-side management.

3.5.4 Charge Controller Sizing

The MPPT charge controller is appropriately sized to handle the PV array's electrical characteristics, ensuring safe and efficient operation.

- Max PV Open Circuit Voltage (Voc): 90.5 V (at -5°C worst-case)
- Controller Voltage Limit: 145 V. The PV array voltage is safely within range
- Controller Current Rating: 35 A
- PV Array STC Short Circuit Current (Isc): 22 A
- Sizing Margin: 159% of Isc exceeds recommended 156.25% threshold

3.5.5 System Resilience and Sustainability

The system's design emphasizes long-term reliability and adaptability. Modular expansion options, such as adding batteries in parallel, support future energy demand growth. High-quality components with extended life cycles contribute to system durability.

- Daily Surplus Capacity: ~3.65 kWh beyond estimated load
- Battery Recharge Assurance: Full recharge achievable even under worst-case solar conditions
- Environmental Advantage: Cool ambient temperatures in Ipi Pata enhance PV module efficiency by reducing thermal losses

The integration of data logging capabilities enables performance monitoring and proactive maintenance. Post-project support and local training foster long-term sustainability and community ownership.

3.5.6 Community Integration and Impact

Community engagement throughout the design and implementation process ensured alignment with local energy needs and affordability. The PV system now supports critical educational and communication functions, including lighting, device charging, and digital learning tools for the primary school.

This installation represents a significant milestone for Ipi Pata, offering reliable electricity access and demonstrating resilience against environmental variability. With surplus generation capacity and appropriately sized components, the system serves as a model for off-grid electrification in similar high-altitude communities.

3.6 Cost and installation

The high initial cost of the photovoltaic (PV) system installation in Ipi Pata was offset through a collaborative funding model involving donor contributions, favorable arrangements with equipment suppliers, and participation fees paid by SAIT student volunteers. As part of the agreement with Light Up the World (LUTW), the community contributed 10% of the system component cost, a significant financial commitment that fosters local ownership and long-term engagement with the project. This approach enabled the deployment of a robust off-grid energy solution without imposing excessive financial burdens on the local community.

Installation was completed over a three-day period by volunteers under the supervision of LUTW staff. Prior to arriving on site, volunteers participated in a full day of training focused on off-grid PV systems, including the specific configuration to be installed and the LUTW methodology. This was followed by a half-day of hands-on practice in wiring and installation techniques to prepare for field conditions.

The remote location and high elevation of Ipi Pata, presented considerable logistical and physical challenges. All equipment, tools, and supplies, including solar panels, batteries, water, and food, were transported from the regional capital of Ayacucho using 4x4 vehicles over unpaved mountain roads.

On site, volunteers adapted to working with unfamiliar materials such as adobe walls and rough wooden structures and learned to pace themselves in the thin mountain air while coordinating tasks effectively in a physically demanding environment. Despite these challenges, the elevated location offered excellent solar exposure due to minimal shading and clear skies. The installation experience not only ensured the successful deployment of the PV system but also provided valuable educational opportunities for all participants.

3.7 Community Reflections: One Year After Installation

One year following the installation of a solar photovoltaic (PV) system at the primary school, a follow-up interview was conducted with the headmaster, a key stakeholder, to assess the project's long-term impact. Using a structured qualitative guide, the interview explored seven thematic areas, offering a comprehensive view of the project's evolution and its effects on education and community life.

- Before the installation, the school operated without electricity, severely limiting its ability to integrate modern educational tools such as tablets, laptops, and internet connectivity. The headmaster's advocacy for a solar PV system stemmed from an urgent need to support digital learning and improve teaching conditions. Despite logistical and financial challenges, including the need to secure co-financing from the Provincial Municipality, the project was successfully implemented.
- Since electrification, the school has undergone a significant transformation. The integration of information and communication technologies (ICTs) has revitalized classroom dynamics, enabling students to engage with digital learning platforms and online resources. Teachers have observed marked improvements in student confidence, participation, and verbal expression, with learners demonstrating greater enthusiasm and comfort in using technology.
- The impact of the solar PV system extends beyond education. The school now serves as a community hub, where residents gather to charge mobile devices and participate in cultural events. Access to electricity has enabled the use of sound systems and other electronic equipment, fostering new forms of communal interaction and inclusion, particularly benefiting families and elders.
- The project is widely regarded as a transformative milestone, elevating both educational outcomes and community morale. It has sparked aspirations for broader electrification, with many residents expressing interest in bringing solar energy to their homes. Local oversight and maintenance of the system have ensured its continued operation, underscoring the importance of community ownership and capacity-building for long-term sustainability.
- Looking ahead, the community has identified access to potable water as its next development priority, given current reliance on untreated water delivered via hose. There is also strong support for replicating similar solar energy projects in neighboring communities, driven by the belief that access to electricity is a fundamental right. The community expressed deep gratitude to the volunteers and organizations involved, affirming the system's reliability and the positive changes it has brought to Ipi Pata.

3.8 Volunteer reflections

The SAIT-LUTW Peru field trip served a dual purpose: to deliver sustainable energy solutions to a remote Andean community and to foster transformative learning among participating SAIT students. Beyond its technical objectives, the initiative was designed to immerse students in a culturally rich environment that would challenge their perspectives, build resilience, and deepen their understanding of global citizenship. To evaluate the personal and educational impact of this experience, a qualitative survey was administered three months after the students returned from Peru. Of the twelve student volunteers, eleven provided responses. The design and structure of the survey were influenced by an online instrument developed by Küver (2013) to explore the impacts of long-term volunteer service among student volunteers in Finland. The survey featured eleven open-ended questions exploring motivations, emotional and psychological shifts, skill acquisition, cultural awareness, and recommendations for future trips. The reflections captured through this survey offer valuable insights into the developmental outcomes of international service learning within a technical education framework.

The responses were analyzed using Copilot to identify key themes and insights. These reflections offer valuable perspectives on the developmental outcomes of international service learning within a technical education framework. The survey responses revealed a compelling blend of emotional growth, technical skill enhancement, and increased global awareness. Students described meaningful transformations in their character, career readiness, and ability to engage across cultures. Below is a summary of the key themes that emerged from their reflections.

- Students were primarily motivated by the opportunity to apply their electrical engineering skills in a meaningful context. Many expressed a desire to help underserved communities, particularly in improving access to electricity for education. The chance to experience a new culture and engage in hands-on learning also featured prominently. For some, the trip aligned with long-term goals such as starting a charity or enhancing their resumes.
- The experience in Peru was described as deeply meaningful and transformative. Participants reflected on the emotional richness of the journey, from connecting with local communities and witnessing the beauty of Peru's landscapes to forming strong bonds with teammates. Physical and logistical challenges, such as illness and high-altitude conditions, were seen as part of the adventure and contributed to a strong sense of accomplishment.
- Challenges were varied and included language barriers, altitude sickness, and physical discomforts like fatigue and digestive issues. Emotional difficulties such as homesickness and stress were also reported. However, students demonstrated resilience by adapting to their environment, learning basic Spanish, and supporting one another through shared experiences.
- The emotional and psychological impact of the trip was profound. Most participants reported increased resilience, adaptability, and self-awareness. The experience deepened their appreciation for cultural diversity and everyday comforts, and for some, it clarified career goals or reaffirmed life direction. The trip was emotionally enriching, with lasting effects on confidence and worldview.
- Students felt their contributions were valuable and essential to the project's success. They played key roles in technical tasks such as solar panel setup, wiring, and troubleshooting. Some provided language translation support, bridging communication gaps between the team and local residents. Witnessing the community's reaction to electricity access was described as deeply fulfilling and transformative.
- The field trip also facilitated the acquisition of practical and soft skills. Students gained hands-on experience with renewable energy systems and developed competencies in teamwork, project coordination, problem-solving, and cross-cultural communication. Personal growth was evident in increased self-confidence, adaptability, and cultural awareness.
- Participants reported a heightened understanding of global and cultural issues. The trip challenged preconceived notions about rural life and highlighted the struggles faced by communities with limited access to basic resources. Many expressed a renewed sense of gratitude and a stronger desire to contribute to global solutions.
- Interactions with people from diverse cultural backgrounds improved after the trip. Students became more empathetic, open-minded, and curious about other cultures. Enhanced communication skills and a deeper appreciation for diversity were common themes. While some noted minimal change due to prior comfort with diversity, the overall trend pointed to meaningful personal growth.

- The experience also prompted reflection on identity and personal strengths. Students identified adaptability, empathy, and technical skills as key strengths, while recognizing areas for growth such as language proficiency and self-doubt. The trip reinforced their values, boosted confidence, and clarified their desire to make a positive impact in the world.
- The most meaningful aspects of the trip varied among participants but included the tangible impact on the community, personal growth, and strong team relationships. Cultural exchange and engagement with diverse perspectives broadened their understanding of the world and reinforced a sense of purpose and global connection.
- Recommendations for future field trips included improved cultural and language preparation, reduced travel fatigue, more immersive local experiences, and better roommate arrangements. Emphasis was placed on ensuring adequate rest, bringing essential supplies, and fostering professionalism and respectful group dynamics.

3.9 From Installation to Impact: Post-Project Review

The off-grid photovoltaic (PV) system installation in Ipi Pata, Huancavelica, Peru, serves as a compelling example of how technical education, sustainable development, and community engagement can intersect to produce transformative outcomes. The project not only addressed a critical infrastructure gap in a remote Andean community but also provided a rich experiential learning opportunity for student volunteers from the Southern Alberta Institute of Technology.

From a technical standpoint, the system design demonstrated a well-balanced approach to energy generation, storage, consumption, expandability and cost. The PV array generation potential consistently exceeded the community center's daily energy requirements, even under suboptimal solar conditions. The battery storage and inverter specifications, while adequate, highlighted the importance of anticipating future load growth and incorporating modularity into system design. The inclusion of high-efficiency components and optimal array orientation further contributed to the system's reliability and performance.

Beyond the technical achievements, the project underscored the value of experiential learning in engineering education. Students engaged in hands-on installation, troubleshooting, and community interaction, which reinforced classroom concepts and cultivated essential soft skills. Survey responses revealed that participants experienced significant personal growth, increased resilience, and a deeper understanding of global energy challenges. The integration of service learning into technical curricula proved effective in fostering global citizenship and intercultural competencies.

The community impact was equally profound. The availability of electricity transformed the educational environment, enabling digital learning and enhancing student engagement. The school evolved into a community hub, facilitating access to communication technologies and fostering social cohesion. The headmaster's reflections illustrated the broader societal implications of energy access, including increased aspirations, improved morale, and a renewed sense of possibility among residents. However, the project also illuminated persistent challenges in rural electrification, namely limited local capacity for maintenance and the need for user education.

The Ipi Pata PV installation exemplifies the multifaceted benefits of volunteer-led sustainable energy projects. It demonstrates that technical interventions, when coupled with educational and community-driven approaches, can yield enduring impacts on both infrastructure and human development. For student volunteers, the project offered a transformative learning experience that bridged theory and practice, while for the community, it delivered tangible improvements in education, connectivity, and quality of life.

As global efforts to achieve Sustainable Development Goal 7 continue, initiatives like this serve as valuable models for inclusive, resilient, and culturally sensitive energy solutions. Future projects should prioritize local capacity-building, and ongoing support to enhance sustainability. Moreover, embedding experiential learning within technical education can cultivate a new generation of engineers, technologists and technicians equipped not only with technical expertise but also with the empathy, adaptability, and global awareness needed to address complex development challenges.

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