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REPRINTED FROM

WIND ENGINEERING

VOLUME 34, NO. 3, 2010

MULTI-SCIENCE PUBLISHING COMPANY
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A Community Small-Scale Wind Generation Project in Peru

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ABSTRACT
Electrification systems based on renewable energy have proven to be suitable for providing decentralized electricity to isolated communities. Electricity generated through wind power is one of the technical options available, although infrequently used to date. This article aims to describe the main aspects of technical design, implementation and management of the first small-scale community wind generation project for rural electrification in Peru. This project took place in the community of El Alumbre, in the region of Cajamarca, which is a mountainous area characterized by low to medium wind speeds. This project, implemented by Soluciones Prácticas - Practical Action (Peru), brought electric power to the 33 households (a total of 150 inhabitants) as well as the school and health center of the community.

Keywords: Decentralized rural electrification, renewable energy, micro wind turbines, developing countries, Peru.

1. INTRODUCTION
Early in the twenty first century, the eradication of poverty and inequality is still a challenge for international development. Although there is no single factor that causes poverty, and the characteristics of which are numerous, the lack of access to energy and technology is one aspect of extreme poverty. An estimated 2.4 billion people depend on traditional biomass for heating and cooking and 1.6 billion people do not have access to electricity [1]. Lack of electricity especially affects rural areas in developing countries, exacerbating the urban-rural divide.

In Peru, according to data obtained from the Ministry of Energy and Mines, an estimated 23% of the population, i.e. nearly 6.5 million people, do not have access to electricity service [2]. The majority of these people live in rural areas, where the situation is even more critical; more than 67% of the rural population in Peru does not have access to electricity. Lack of energy tends to act as a barrier, preventing families from overcoming poverty. Usually, in rural

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communities, poor families spend an average of $US 5 a month on candles, kerosene and/or batteries [3]. Access to electricity systems would not only imply a saving, but would have the following positive impacts on the benefiting families:

- Providing higher-quality energy, replacing burners, kerosene lamps and candles that produce smoke and thus can damage eyesight and lungs.
- Extending the productive hours of the day and allowing children to do homework in the evenings.
- Increasing access to means of communication like radios, television and cell phones.
- Boosting the local economy by powering machinery to add value to local products, such as mills and carpentry shops.
- Improving health by refrigerating vaccines and electrifying medical devices.
- Powering computers for schools.

The conventional strategy for increasing access to electricity in rural areas is to extend the national electrical grid. However, due to the extensive and complex geography of Peru and the dispersed nature of its small villages, the extension of the national electrical grid to reach all rural households would be economically prohibitive. Under these circumstances, other technologies based on the development of renewable local resources could give isolated communities the opportunity to gain access to decentralized, sustainable and locally managed energy services. Electrification systems based on renewable energy have proven to be suitable for providing decentralized electricity to isolated communities around the world. These stand-alone systems are often much cheaper than grid extension. Moreover, one of their main advantages is that they use local resources and avoid external dependences, which in turn, promotes the long term sustainability of the projects.

Among the technical options available, micro hydro, photovoltaic systems and micro wind are the most widespread. Usually, where a water resource is available, micro hydro projects are the best option as they provide continuous energy at a low cost per kilowatt hour. Where there are no appropriate rivers, photovoltaic systems are usually chosen, although they are an expensive option. Small windpower is a little known option worth taking into consideration [4]. In windy regions, wind systems can be cheaper than photovoltaic systems that provide the same energy output. Moreover, wind turbines can be locally manufactured whereas solar panels are only manufactured in several countries. The existence of local manufacturers facilitates the system maintenance and has the advantage of promoting enterprise development.

Micro wind electrification systems are an alternative with great potential for generating power in rural areas, though infrequently used to date. Most wind electrification projects consist of the installation of only one turbine [5, 6, 7], even though they are community projects. In most of these projects the wind turbine supplies electricity to the residents of the community through battery charging services. There is one experience in Kenya in which one community turbine supplies electricity through a microgrid [8]. Very few projects have used more than one turbine [9]. An exception to this has been in Argentina, where an important institutional effort has been carried out for developing rural electrification projects in Chubut [10]. In the flat plains of Patagonia, a number of individual systems for rural households have been installed, and some rural village schools were also electrified with a few wind turbines.

To our knowledge, the project in El Alumbre (Peru) has been the first experience of micro wind electrification projects in mountainous areas, using individual wind turbines at each family household, and it was the first small-scale community wind generation project for rural electrification in Peru. The installation process in El Alumbre started in January 2008 and was completed in January 2009. This article aims to describe the aspects of technical design, implementation and management of the project. This project was promoted by the NGOs Soluciones Prácticas – Practical Action, from Peru, Engineering Without Borders – Catalonia (ESF), from Spain, and Green Empowerment (GE), from USA, with support from Research Group on Cooperation and Human Development of the Technical University of Catalonia (GRECDH-UPC), from Spain.

The rest of this paper is organized as follows: Section 2 introduces the community of El Alumbre. The technical description of the project is presented in section 3. Section 4 explains the management model. Section 5 presents the evaluation and results and finally, section 6 summarizes the conclusions.

2. THE COMMUNITY OF EL ALUMBRE

2.1. Context of El Alumbre

The small community of El Alumbre is located in the region of Cajamarca. Cajamarca has an area of 33,317 km^2 and a population of more than 1,400,000 people, representing approximately 6% of the country. Seventy-two percent of the population of Cajamarca live outside cities. Cajamarca is one of the poorest regions in Peru and 64.5% of the population live below the poverty line (with incomes lower than national poverty line) [11]. The Human Development Index of Cajamarca is 0.540 (the national average is 0.598) [12]. The Infant Mortality Rate in Cajamarca is close to 83 per 1000 newborns [11]. Its illiteracy rate is more than 16%, and higher among rural women [12]. The main economic activities are mining and agriculture. Cajamarca has the lowest electrification rate in the country: 40.2% [11].

Cajamarca is located in the mountainous area of northern Peru. The recently developed wind resource atlas of Peru [13] has confirmed that Cajamarca is one of the areas with the highest wind resources in the country (Figure 1).

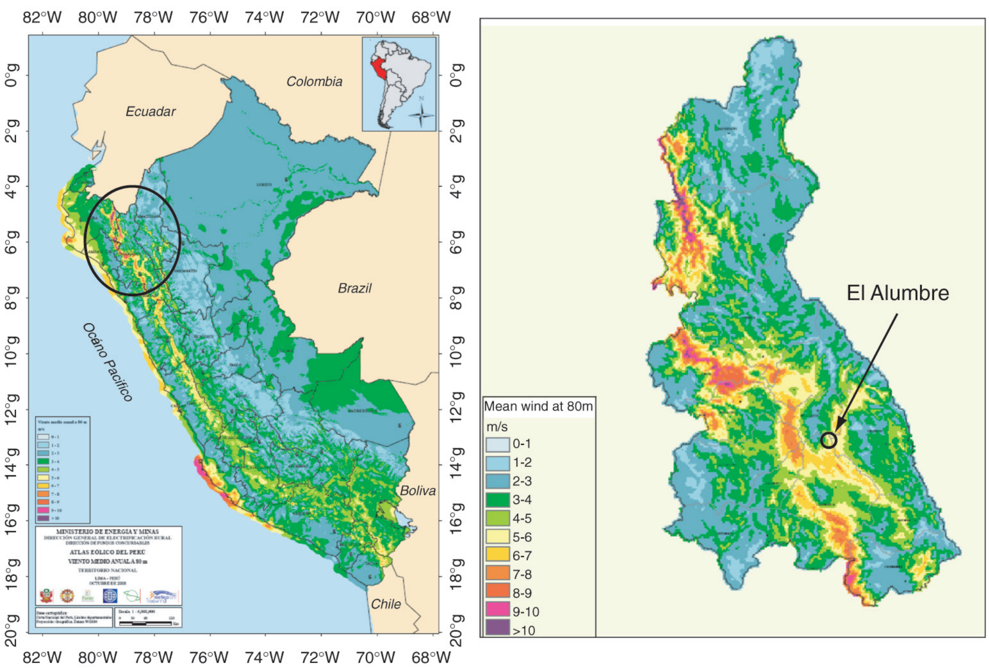

Figure 1: Cajamarca region (left). El Alumbre in the mean wind speed map at 80 m [10].

Figure 2: View of the center of El Alumbre, where the anemometer was installed.

Thirty-three families (150 inhabitants) live permanently in El Alumbre. They are mainly engaged in subsistence agriculture and livestock rearing. Throughout the year, the climate is cold, with an average rainfall of 827 mm during the months of January to April, and with the presence of strong winds during the months of July, August and September. The average temperature during the day is 8°C and it declines at night below 0°C. In the center of the village there is a cluster of several households, the schools and the health post (Figure 2). However, the rest of the population is quite dispersed; the 33 houses are spread out over 10 km^2. At the time of identifying the community for the project, the community was not included in any plans to extend the national electrical grid.

2.2. Socioeconomic Analysis

The purpose of the socioeconomic study was to analyze and understand the following characteristics of the families: social, economic, energy consumption and demand, organizational level, identification of individual and group capabilities [3]. The study was an important first step in the development of the management model with local service administration. The instruments used to collect information included socioeconomic surveys of each family, interviews with local authorities and representative residents, and a focus group with the local organizations and representatives.

The population is relatively young; 71.4% are younger than 30. In El Alumbre, the majority of the population have partially or fully completed elementary school. Only one person had higher education at a technical school. However, only 9.5% of the population is illiterate, all of whom are women.

Cattle rearing is the most important economic activity, as sale of milk and occasionally fresh cheese (*quesillo*) provides almost the only cash income. Complementary sources of income include sale of labour and selling a small portion (20%) of their agricultural products. The most common agricultural crops are: potato, barley and native tubers (*oca* and *olluco*). Eighty percent of the agricultural production is for subsistence consumption. The population can be characterized by 3 types of economic divisions: 21% have an average monthly income of less than $US 30, 52% have a monthly income between $US 30 and $US 65, and the remaining 27% have monthly incomes ranging from $US 65 to $US 120.

There is considerable temporary work migration. Of the total number of families, 13.8% migrate to sell their labour in agricultural activities, principally on the coast or in the jungle, for 3 to 4 months from January to April. Those who migrate are the fathers and older sons of the families, leaving mothers and children at home.

The principal sources of energy were candles, kerosene, car batteries and small appliance batteries. The average expenditure on energy was 15.67 soles (approximately $US 5) per month. In terms of electrical appliance use, most people had battery-powered radios, and some have sound systems or cell phones (that they charged during trips to the city). The estimated future energy demand was around 380 Wh/household/day considering that they will progressively buy other home appliances such as sound systems and TVs.

The most important community organizations locally present are the municipal representation of the village, the *Ronda Campesina* (community patrol group) and the deputy governor. These institutions are accepted by the entire community and have the power to call official meetings. For the implementation of the project, these were the appropriate links between SP-ITDG and the population of El Alumbre.

2.3. Wind Resource

El Alumbre is a community located in the Andes of northern Peru at 3850 meters above sea level. The terrain is steep and there is almost no vegetation other than wild grasses. In the first visits to the project area, it was noted that the area has appropriate mountainous terrain to have good wind potential. An anemometer was installed in the center of the community to measure the wind resource in detail; it was installed on a 10m height tower, on flat terrain with no obstacles that may influence the measurements.

Wind measurements were taken for more than a year, but the wind resource analysis was primarily focused on the months with the least amount of wind. The system must be designed according to periods of the year with the lowest wind resource in order to guarantee that there is sufficient electricity generated meet the demand throughout the entire year. Figure 3 shows the analysis of the daily wind resource available based on the months which have the

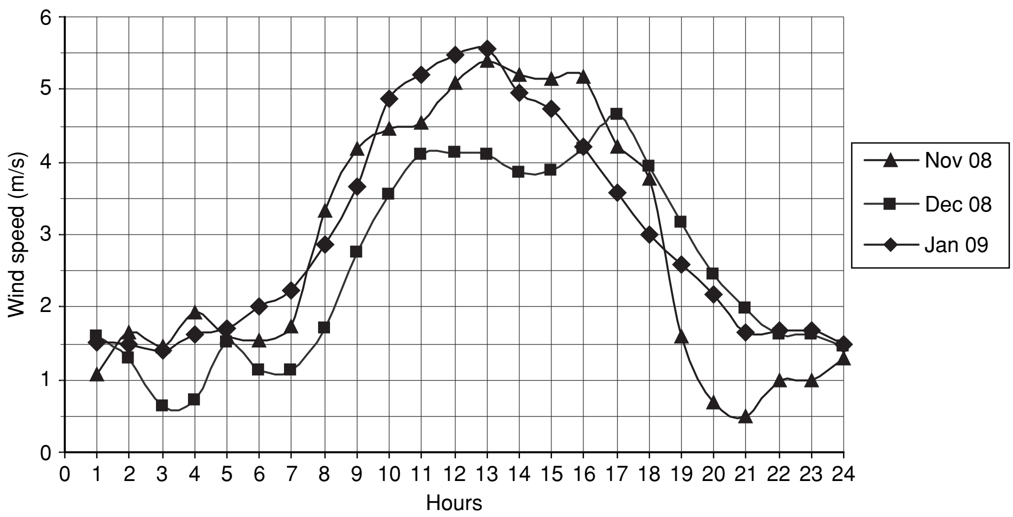

Figure 3: Daily wind resource in El Alumbre, from November 08 – January 09.

least wind, November – January. The graph shows that, in the lowest wind months, wind velocity measures approximately 3.5 m/s. This is a low to moderate wind resource, but enough to cover the electricity demand of the community with wind energy. During the months with the highest wind (July – September) the average wind speed reached 9 m/s during the windiest hours of the day (around 1 pm).

3. TECHNICAL DESCRIPTION

The electrification project is designed to cover basic household needs and community services (a school and a health center). As the distance between households was great, and thus energy consumption points were scattered, the project organizers decided to install an individual wind turbine at each consumption point instead of connecting points in a small grid. The project was implemented in two phases. In a first phase, in January 2008, 21 wind turbines of 100 W (model IT-PE-100) were installed in 21 homes and a wind turbine of 500 W (model SP-500) was installed in the school. In a second phase, in January 2009, 12 more family systems and a 500 W wind turbine were installed to electrify homes and the health center, respectively. In the first phase, turbines were installed on 7 m high towers. Due to the lack of wind resource, and thus energy at some points, several 7 m towers were changed to 10 m towers to reach the higher wind resources. The turbines of the second phase were directly installed on 10 m towers.

The wind turbines installed are models developed by SP-ITDG [14] (Figure 4). In 1998, ITDG began a long-term research study focused on taking advantage of small wind energy to generate electricity for poor rural families in three countries: Peru, Sri Lanka and Nepal. In the case of Peru, the technical characteristics were defined and a number of recommendations were made: the design should use the low wind speeds that predominate in Peru and allow local manufacturing in order to ensure the technical sustainability and the long-term supply of spare parts, among other considerations.

The turbines developed were specifically designed to operate at low wind speeds. IT-PE-100 operates with wind speeds from 3.5 m/s to 12 m/s, and produces 100 W at 6.5 m/s

Figure 4: Installed wind generators, of 100 W (left) and 500 W (right).

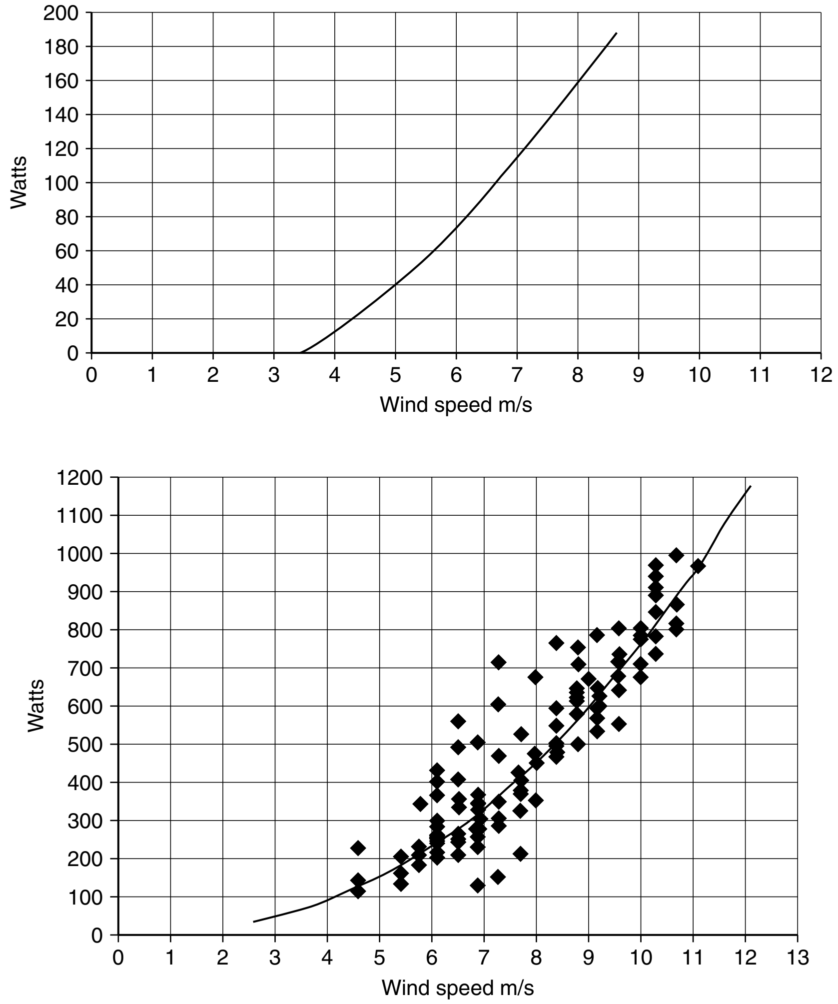

Figure 5: Power curve of the IT-PE-100 and the SP-500, respectively [12].

(Figure 5). SP-100 operates with wind speeds from 3.5 m/s to 12 m/s, and produces 500 W at 8 m/s (Figure 5). Both models are furling tail turbines with 3 fibreglass blades and axial permanent magnet generators. The wind turbines are manufactured by a local company in Lima, thereby stimulating business creation and facilitating repair and parts replacement. These designs prioritize robustness and ease of maintenance, essential for project sustainability.

At each point of consumption, the equipment installed included a controller, a battery bank and an inverter to facilitate the use of AC equipment (Figure 6).

The population actively participated in the entire process of equipment installation (Figure 7): preparation of the holes for the base of the towers, installation of the towers, construction of the control panel, and internal wiring of the homes. The entire community contributed work during both installation phases, even those who had to wait until the second phase of installation or those who already had completed their home installation in the first phase.

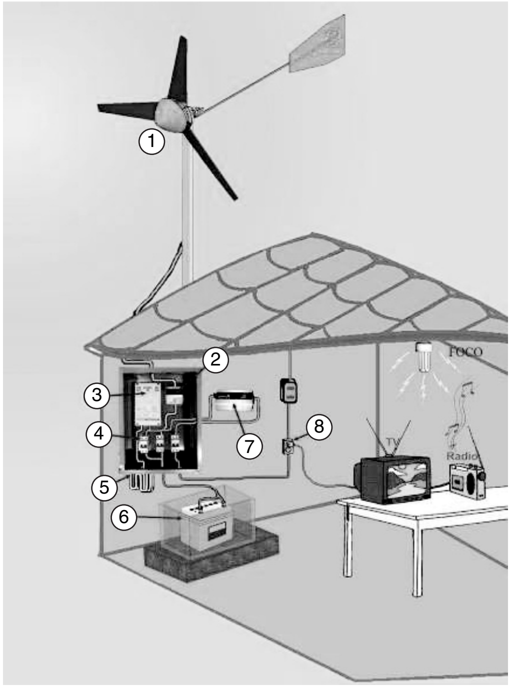

Figure 6: Equipment installed at each consumption point [14].

Figure 7: Installation process of the turbines and the battery controllers.

4. MANAGEMENT MODEL

A common challenge in isolated electrification systems is guaranteeing the long-term sustainability of the projects by insuring sufficient maintenance and access to replacement parts. To support this, the project organizers focused on the development of an appropriate management model. The management model designed takes into account the internal social relations of the community, its forms of organization, values, and group and individual capabilities. To achieve sustainability of the system, the management model is based on three key points: create a micro enterprise to manage the services, strengthen the capabilities of the residents and assure commitment and participation of the population. The management model is composed of different components and actors (Figure 8) including the micro enterprise, a users committee, the municipality and the NGO.

In order to guarantee an efficient operation and administration of electrical service, the management must be independent of the interferences of political or personal interests. A local micro enterprise has been formed to operate, maintain and administer all of the systems.

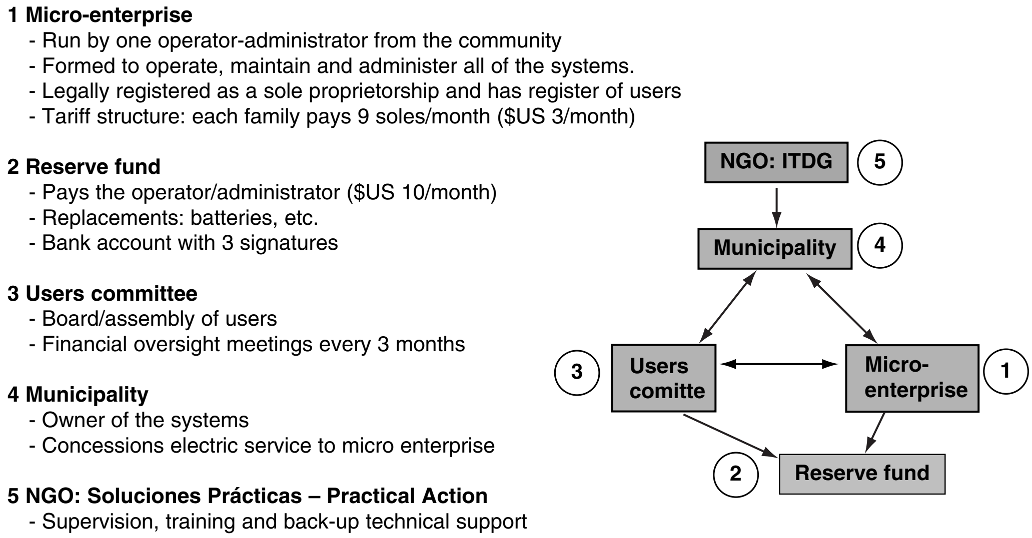

Figure 8: Overview of management model.

The formation of the small business promotes an entrepreneurial culture and provides local technical assistance when minor breakdowns occur. The micro enterprise is legally registered, maintains a written service contract with the users and has a tariff structure. Organizers introduced the concept that energy generation and distribution is a *service* to the users, and thus should be paid for. The micro enterprise is in charge of collecting a monthly tariff paid by the users and serves to cover the costs of maintenance and replacement of the equipment throughout the lifespan of the project. The tariff also serves to provide a stipend to the operator-administrator. The monthly tariff was set at 9 soles (approximately $US 3), which is less than the average expenditure that the families were using for energy (candles, kerosene, etc.). The reserve fund is kept in a bank in the closest city and requires 3 signatures to access: the micro enterprise operator-administrator, a community authority and an energy user. The micro enterprise combines the benefits of small businesses with the values of community participation.

Taking advantage of, and developing, the existing local skills is a goal of the project and key to guarantee sustainability. Thus, it was decided that the micro enterprise should be composed of one or more of the residents of El Alumbre, selected and trained to take over the operation and maintenance of the systems. First, the community itself nominated candidates to run the micro enterprise in an open meeting. Then, all of the eight candidates participated in a comprehensive training program which covered both administrative and technical skills, such as basic accounting and electrical wiring. The advantage of training more than the selected operator-administrator is that it contributes to a fair and transparent process, and also builds the capacity in more than one person so that other people will be able to step into the management role in the future. At the end of the training workshops, the participants completed a written test on the basic concepts. Then, a committee composed of community leaders and the project organizers compared candidates based on test scores as well as criteria such as past community involvement and reputation within the community. The top candidate was selected to be the operator-administrator and a back-up person was selected to provide assistance.

The operator-administrator has incentives to provide quality service because he receives a small stipend ($US 10/month), there is a sense of honor in serving the community and also because there is a formalized oversight process. The users committee (composed of the entire community) has the right of financial review meetings every 3 months. Furthermore, periodically the community will evaluate the performance of the micro enterprise and re-elect the current, or a new, operator-administrator to run the micro enterprise. The legal owner of the system in this case is the municipality. The municipality signs a concession contract assigning the service management to the micro enterprise, thus it cannot interfere with the day-to-day operations such as setting the tariff. However, as legal owners, the municipality shares the responsibility of replacing equipment in the long run to complement the community's reserve fund. The municipality also has the right to move the systems to another community if the national electrical grid should eventually arrive to El Alumbre. Finally, the project organizers supervise the functioning of the system and support the other local actors. Thus, there is a system of checks and balances which stimulate efficient and fair management of the electrical services (Figure 8).

Finally, it is critical to promote the active participation of the beneficiaries, representatives and community leaders in the entire process of project implementation. In the project identification phase, meetings were held with all of the beneficiaries to explain in detail the advantages and limitations of the energy systems as well as their rights and responsibilities so that the energy supply is maintained. These responsibilities include the active participation in the installation of the system and a commitment to pay a monthly tariff to guarantee the maintenance and replacement of the equipment. Users were trained on both technical and administration topics; how to operate the household equipment, read the controller, manage battery charging and understand the tariff and late fees. A training program included education for all the inhabitants on the proper use of energy; such as the use of energy efficient light bulbs and the prohibition of irons or other equipment that would not work with the system. The theoretical lessons took place at the school and the practice was undertaken during the installation of the systems. The implementation of the management model developed in parallel to the installation of the systems, and promoted participation of the entire village.

5. EVALUATION AND RESULTS

Follow-up and evaluation of the project in El Alumbre is especially important in this project since it is a pilot experience in the implementation of locally-manufactured small wind turbines (100 W and 500 W). Thus, follow-up has been undertaken by the NGOs (SP-ITDG, ESF-Cat, GE) and universities (GRECDH-UPC) to evaluate results. Monthly visits were carried out since the beginning of the project with the purpose of reviewing the systems and supervising the use of batteries, controllers, and other accessories. The generation of electrical energy was evaluated and households were surveyed to see if their energy needs were being met. The visits also focused on the social aspects of the project and strengthening of the management model.

The first evaluation was completed after the first phase of the project, through house-to-house surveys, a focus group and the installation of dataloggers to monitor electricity generation and use in some points. After two years, another evaluation will be undertaken to measure the impact on the project beneficiaries. To date, the evaluations have revealed the following results:

- Wind turbines installed in each home cover the domestic use of electricity for 5 hours/day. The evaluation survey found that 100% of households use the system for lighting, 57% are now weaving or knitting in the evenings, 64% are using the lighting for studying, 43% have radios and 93% are charging cell phones. Energy in the school powers four computers (with electronic encyclopaedias) and a DVD player for educational videos, used by 80 students from El Alumbre and neighbouring communities. The health center, which serves 4 communities, now has electricity for lights, sterilizer and a vaccine refrigerator.

- As a result of the wind turbines, 70% families are expressing a reduction in expenditures in other energy sources such as kerosene or candles. Moreover families have been using energy in a direct or indirect way in the implementation of small businesses such as a radio station and weaving.
- Neighbouring communities have also benefited by being able to charge cell phone batteries. At the same time, residents of El Alumbre have benefited from the small fee paid for cell phone charging.
- The El Alumbre micro-enterprise for rural electrical services has been successfully operating for nearly two years. The introduction of concepts of customer service in the structure of a single person micro-enterprise has been shown to be an innovative way of promoting sustainability.
- The operation and maintenance of the systems has been strengthened through the use of small visual manuals [15] and the participation of authorities and the local technician in the community training sessions.

6. CONCLUSIONS

This article describes the aspects of technical design, implementation and management of the project in El Alumbre (Peru), which is the first small-scale community wind generation project for rural electrification in Peru. The project installed 35 individual wind turbines at households, a secondary school and the health post. Thanks to this project, the residents of El Alumbre benefit from lights, improved communications, and economic savings. They have been able to develop small businesses and improve public services in the school and clinic. The micro enterprise combines the benefits of small businesses with the values of community participation. The management model is proving to be successful in guaranteeing the sustainability of the project and strengthening local skills and entrepreneurship.

The El Alumbre project has demonstrated the viability and relevance of taking advantage of local renewable resources to generate electricity, in particular wind. Local, regional and sector officials and authorities have now an example ready to be replicated and disseminated on a larger scale.

ACKNOWLEDGEMENTS

This project was funded by The Co-operative Bank and The Koru Foundation from United Kingdom, the Asociación Catalana de Ingeniería sin Fronteras and the Technical University of Catalonia from Spain, Green Empowerment of the United States, and the Wuppertal Institute for Climate, Environment and Energy (WISIONS) from Germany. The authors also appreciate the active participation, facilitation, understanding and enthusiasm of the community members of El Alumbre.

REFERENCES

1. International Energy Agency, World Energy Outlook, 2004.
2. Ministerio de Energía y Minas, Dirección Ejecutiva de Proyectos, Informe de Gestión Anual 2007, Perú, Enero 2008.

3. Mantilla, W., Diagnostico socioeconomico localidad: El Alumbre. Programa de energia, infraestructura y servicios basicos – ITDG, Cajamarca, 2007.

4. Coello, J., Escobar, R., Dávila, C., Villanueva, G., and Chiroque, J., Micro hydro power plants and other alternative energies: contributions of Practical Action – ITDG to rural development, *Environmental Cases Studies and White/Technical Papers*, *Port of Entry, the Environmental Business Network for the Americas*, 2006.

5. Chongo Cuamba, B., Planning wind energy parks in Mozambique, *International Workshop on small wind energy for developing countries*, Nairobi, Sep 2009.

6. Ceesay, S., Case study from the Gambia, Access to Modern Energy Services, Community driven electrification using Wind Energy and challenges for Regulators. *International Workshop on small wind energy for developing countries*, Nairobi, Sep 2009.

7. BlueEnergy (http://www.blueenergygroup.org/index.php)

8. Crafskills (http://www.craftskills.biz/)

9. Intermediate Technology Development Group, Nepal, http://practicalaction.org/nepal/region_nepal.

10. Seitz, M., Patagonia wind aids remote communities, *BBC News*, 10 February 2006.

11. INEI, Instituto Nacional de Estadística e Informática, La pobreza en Peru en el año 2007, 2007.

12. PNUD, Programa de las Naciones Unidas para el Desarrollo, Informe de desarrollo humano del Peru, 2005.

13. Meteosim Truewind S.L., Latin Bridge Business S.A., *Peru Wind Atlas*, 2008, Available at www.foner.gob.pe/atlaseolicolibro.asp.

14. Chiroque, J., Microaerogeneradores de 100 y 500 W. Modelos IT-PE-100, SP -500, Soluciones Prácticas-Intermediate Technology Development Group, 2008. (http://www.solucionespracticas.org.pe/publicaciones/pdf/Microaerogeneradores%20de%20100%20y%20500%20W.pdf)

15. Chiroque, J., Micro aerogeneradores de 100 w para uso doméstico en zonas rurales. Manual para usuarios, Soluciones Prácticas-Intermediate Technology Development Group, 2008. (http://www.itdg.org.pe/publicacionessp/publicacion.php?id=MzE2)