7

Promoting and Improving Renewable Energy Projects Through Local Capacity Development

Rafael Escobar[1], David Vilar[2], Enrique Velo[3], Laia Ferrer-Martí[3] and Bruno Domenech[3]
[1]*Practical Action*
[2]*Engineering Without Borders*
[3]*Universitat Politècnica de Catalunya-BarcelonaTech,*
[1]*Peru*
[2,3]*Spain*

1. Introduction

Early in the 21st century, an estimated one and half billion people lacked access to electricity and three billion people, almost half of the world population, still rely on solid fuels and traditional biomass to meet their cooking needs (WHO, 2009). The important role of energy systems in the design of a sustainable development model has been recognized worldwide (Modi et al, 2006). It is estimated that, to achieve the Millennium Development Goals (MDG), among other goals, it is necessary "To provide access to modern energy services (in the form of mechanical power and electricity) to all rural communities".

Electricity effectively contributes to improve living conditions of people (Chaureya et al, 2004) through services such as night lighting (domestic and public), access to information and communications, drinking water and sanitation, medical assistance and education, and creates opportunities to generate incomes and jobs. Likewise, electricity can contribute efficiently to social empowerment, promoting equity and empowerment of women.

Nowadays, technologies that use renewable sources are considered appropriate for energy supply in isolated rural communities with autonomous systems (Chaureya et al, 2004). However, there are barriers that difficult this process, related to the social, technological, economical, financial, institutional or political context. Although in the countries of the Andean Community of Nations, some institutional and political barriers are starting to be overcome, lack of capacity and high investment costs remain major barriers (Figure 1), which slow down the rural energy development in the region.

In the Andean region, technical teams, municipalities and regional governmental authorities, community leaders and base organizations often have limited knowledge about the potential of renewable sources. Thus, despite belonging to organizations that should promote the development of poorest populations, they do not exploit the benefits of their potential for the implementation of energy systems and the increase of beneficiaries' quality of life. Due to this lack of knowledge and sometimes lack of confidence in renewable energy technologies, these organizations usually do not consider renewable sources within their energy options portfolio. On the contrary, they focus on grid extension and the implementation of diesel generators that in most cases increase the indebtedness of countries and communities, and mortgage their development options. In addition, many rural electrification projects implemented with renewable sources in recent decades have collapsed or are in a precarious state, mainly because of lack of proper and complete training of beneficiaries (Vilar et al, 2006), both in operation, maintenance and management models, poor (or nonexistent) identification of their needs, and low (or no) community involvement throughout the process.

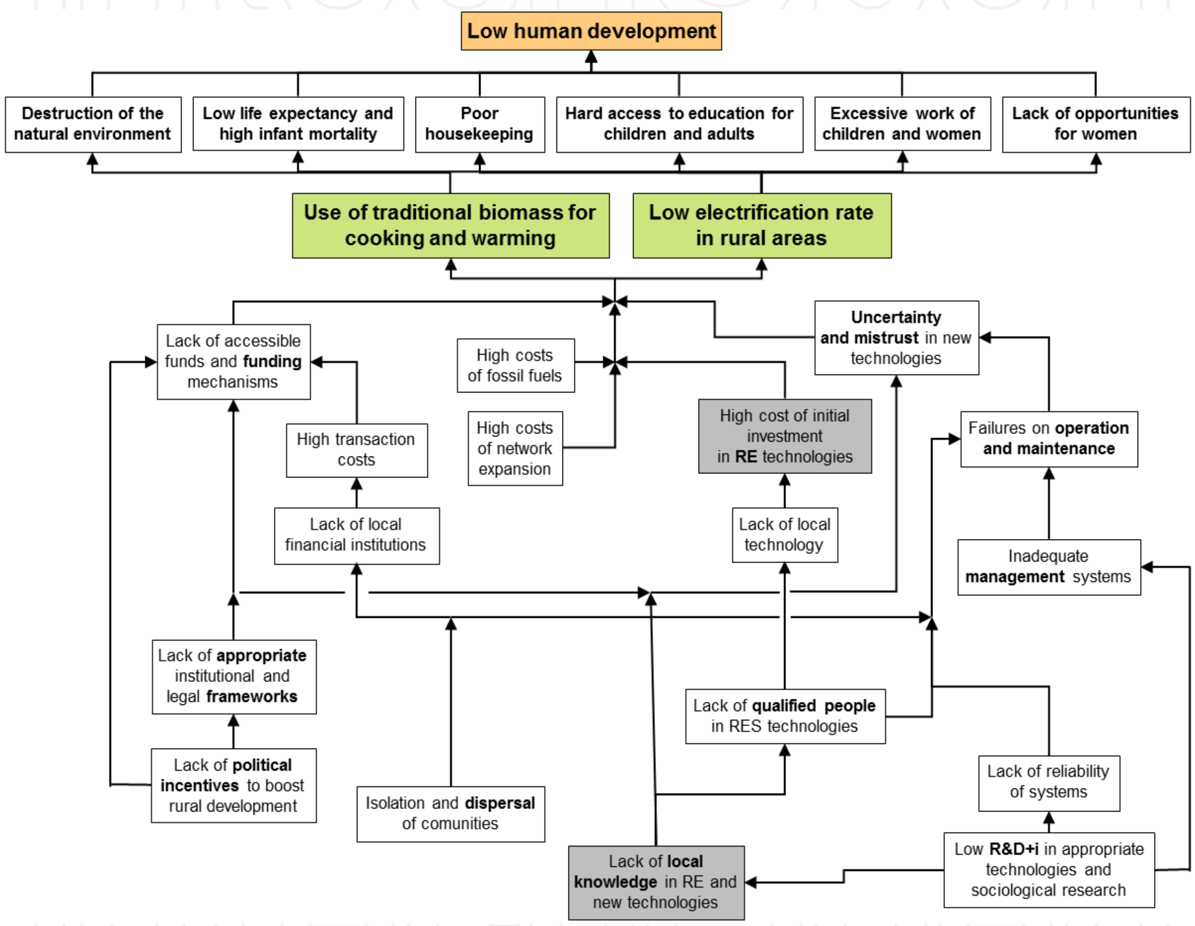


Fig. 1. Barriers that slow down rural energy development

The key factors for sustainability success and reduction of initial and maintenance costs of isolated energy systems (Figure 1) are: community participation, strengthening of community organization, training in management methods and, if possible, training of local manufacturers for the production of equipment and components (PNUD, 2005b). Consequently, capacity development of local and regional leaders, planners as well as technicians training, is an increasingly pressing need.

In this context, Practical Action (Peru), Engineering Without Borders-ISF (Spain), Universitat Politècnica de Catalunya (Spain) and Green Empowerment (USA) developed the project CEDECAP (Demonstration and Training Centre in Appropriate Technologies). Its specific aim is to develop technical and management capacities and offer training in the framework of access to energy and use of renewable sources, and to create a knowledge and research network in the Andean zone. One of the most noteworthy innovative aspects of CEDECAP is the creation of new spaces to canalize and share knowledge and create new synergies between different actors of public or private development. The objective goes beyond the simple approach of the punctual impartation of training lessons or technical demonstrations; the purpose is to insert capacity development and networking in the infrastructure and service policies in order to assure the sustainability, improve the projects' impact and promote the role of renewable energies (RE) in rural areas.

The CEDECAP began as a support center for training and design of electrification projects that their promoters, mainly Practical Action, were carrying out in the rural areas. However, the center's scope has been expanding and now has the following action lines: capacity development, research, dissemination and incidence, always maintaining its initial support to the implementation of projects. The following sections present each of these lines. Section 2 presents the overall project, the center, and its installations. Section 3 explains how CEDECAP supports the implementation of the projects. The capacity development and the training offer are summarized in the section 4. Section 5 introduces the main research activities developed in CEDECAP and section 6 presents the CEDECAP's role as information and advocacy node. Section 7 explains how the developed planning methodologies include the four working activities presented in previous sections, and finally section 8 is devoted to conclusions.

2. The project CEDECAP

Initially, Practical Action – ITDG boosted the construction of a training center, promoted through its programs operating in Cajamarca, as part of its institutional proposal of development of local and regional capacities and promotion of renewable energies as an alternative for rural development. After several years of preliminary activities, in 1998, the CEDECAP (Demonstration and Training Centre in Appropriate Technologies) was officially opened, with the main objective of promoting activities aimed at the training human resources and the strengthening of capacities in the field of renewable energy, with preponderance on mini-hydraulics.

Since 2005, through a partnership between the Catalan Association of Engineering Without Borders (ESF) from Spain and Practical Action – ITDG from Peru, a more sustained work was promoted to achieve the consolidation of CEDECAP as a reference in the field of capacity development. The project CEDECAP was part of the Andean Program of Rural Electrification developed by ESF in countries such as Ecuador, Bolivia and Peru. The main purpose of the program was to improve the quality of life of the Andean population, through the universal access to energy in the area, especially through renewable sources. The specific objective was to develop technical and management capacities, and offer proposals for training, creating a network of knowledge and research in the Andean region (mainly Peru, Ecuador and Bolivia) in the context of access to energy and use of renewable sources, under the approach of technology for human development (Fernández-Baldor et al, 2009). Now, Peruvian (Pontificia Universidad Católica de Peru – PUCP) and Spanish (Universitat Politècnica de Catalunya – UPC) universities participate in the advisory body of the center to give support in the definition of courses and in the strategy.

As detailed below, CEDECAP facilities currently do not only have energy modules but also other thematic areas of rural development, such as information and communication technologies, and water and sanitation. There are also accommodations where students can stay during the courses. In view of coming years and the relevance the center is taking, there are plans to expand the accommodations, build offices and a dining hall, and create a working module in the area of agronomy to strengthen capacities development in the area of production (Figure 2).

Fig. 2. CEDECAP facilities at present and those planned

At the same time, the CEDECAP aims to enhance networking among different reference groups in the South working on access to energy and defense of rights in the exploitation of natural resources, to facilitate coordination, social connectedness, knowledge sharing and interaction between different actors involved in Education for Sustainable Development (UNESCO). Figure 3 shows a scheme of the continuous process of strengthening and local capacity development, in short and long terms. The strategy of the CEDECAP is formulated under this conceptual process. The objective goes beyond the simple approach of the punctual impartation of training lessons or technical demonstrations; the point is to insert capacity development and networking in the infrastructure and service policies in order to improve the projects' impact and to promote the role of renewable energies in rural areas.

2.1 Objectives and strategy

The CEDECAP's vision is to be the leader in capacity development for the implementation and use of appropriate technologies in Latin America. For this purpose, the center has the main objective to strengthen technical and management capacities of leaders, students, manufacturers, technicians, professionals and government's employees for the formulation, implementation and monitoring of appropriate technological systems and to be able to formulate policy proposals, in order to support the development of rural areas.

The CEDECAP's stakeholders are the government (regional and local agencies), civil society (base associations and organizations), under-national and local governments, private companies (local decision-making institutions) and academic institutions (universities and institutes). It is a priority to establish partnerships with the different actors through the development of a capacity offer in order to ensure CEDECAP's sustainability; these partnerships will allow the center to accomplish the mission within the period covered by this strategic proposal.

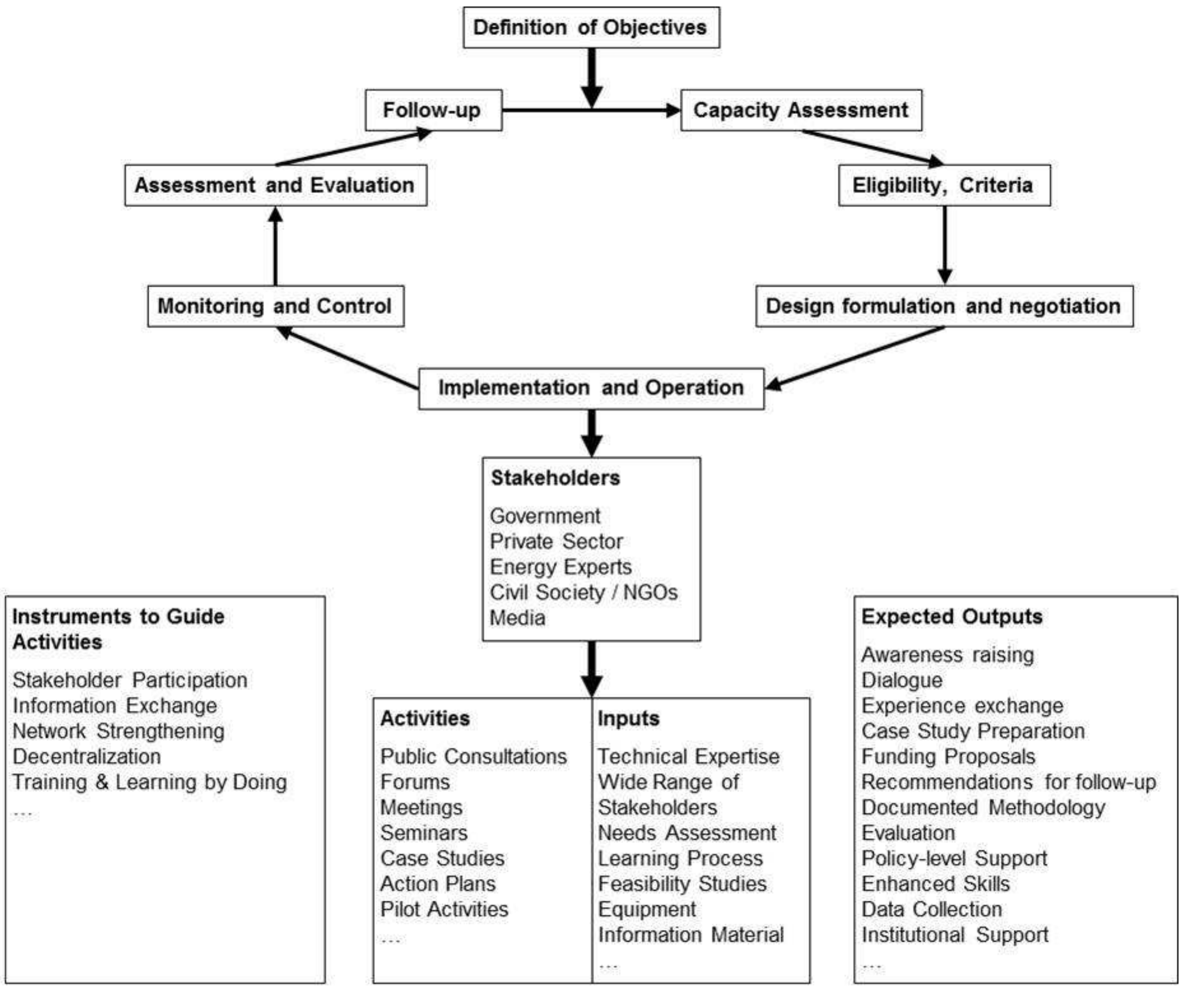


Fig. 3. Interventions on capacities development: planning and implementation cycle [adapted from Bouille and McDade, 2002]

The CEDECAP's initial working area was only energy but, after a while, an information and communication technologies module and water and sanitation area were added. Recently, a still incipient agronomy area has been initiated. None of the thematic areas is independent, they are all interrelated with the others, either by the type of institutions promoting capacities development, or by the type of target audience or by the teaching tools used to accomplish the goals. Although probably the area with higher impact levels is still the energy one, the objective of having a range of beneficiaries trained in the field of appropriate technologies will be accomplished through the intervention in all the thematic areas.

CEDECAP's principles are: a) to generate knowledge through applied research and development and technology transfer; b) to disseminate knowledge through the continuous training proposal that will be developed at the regional level; c) to transform the framework, which can be achieved through the access to information and advocacy. All this will be done through developing and offering a training proposal to meet current and future demands for training in renewable energies and related issues.

The following figure (Figure 4) illustrates CEDECAP's strategy and the tree constructed in order to consolidate it..

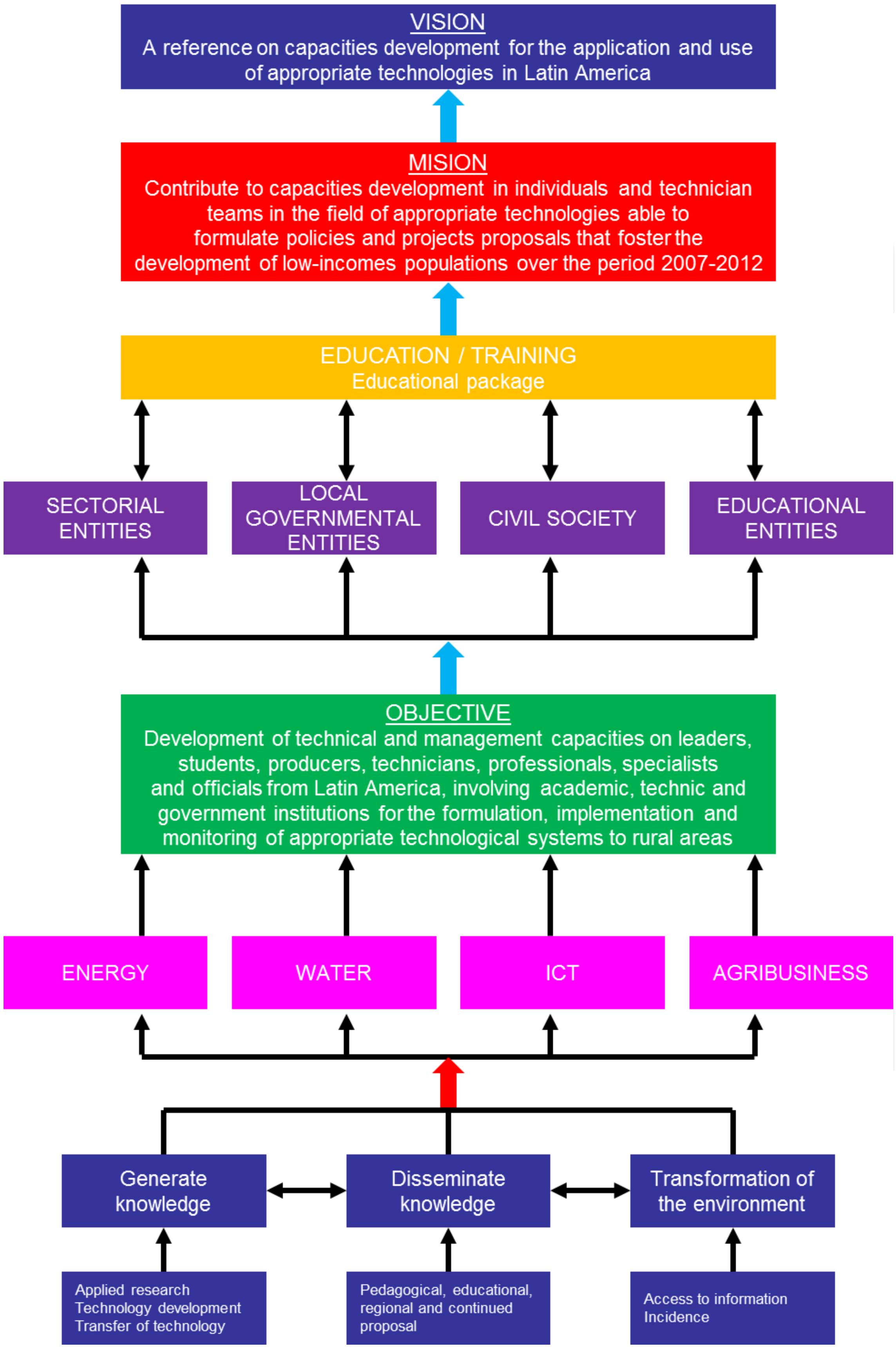


Fig. 4. General strategy of the CEDECAP

Making a bottom-up description, on the lowest level there is the importance of developing activities in the field of generation, diffusion and transformation in the four areas (energy, information and communication technology, water and sanitation, and agronomy). Then, the key actors (local governmental agencies, civil society and educational institutions) are approached with an offer of full and comprehensive training that contributes to strengthen individuals' and teams' of technical capacities in the field of appropriate technologies, turning the CEDECAP on a reference in capacities development for the implementation and use of appropriate technologies in Latin America.

Although, as it has been mentioned, the CEDECAP has different thematic areas, this work mainly focuses on presenting the energy one, which is the promoter and still the one that is far more developed.

2.2 Installations

The CEDECAP is located in Llushcapampa, 20 km from the city of Cajamarca, and has an area of around 6.000 m^2. CEDECAP was built in the area of a former hydroelectric power plant, so it has a loading chamber and the presence of falling water. CEDECAP construction began in 1999 and was held in several stages. The CEDECAP has real-size facilities that are used both for training and for research purposes. The CEDECAP's equipment started in relation to energy, and nowadays there are hydro, photovoltaic, wind and hybrid energy generators. Recently, information and communication technologies module and water and sanitation installations have been added.

2.2.1 Energy module

The energy module has facilities in relation to micro hydro, wind and photovoltaic power (Figure 5):

- A micro hydropower module with 3 pico-turbines of 0,8, 1 and 5 kW, plus an electronic control and regulation equipment, banks of electric resistors, and other supplementary equipment.
- A micro wind energy module with 2 micro-wind generators of 100W that were designed by Practical Action (Peru). One of them is in use while the other one is taken apart to be used in practical lessons.
- A photovoltaic energy module with solar panels from 50 to 80 W mountable in workshops.

Fig. 5. Micro hydro (left), wind (center) and photovoltaic (right) modules

2.2.2 Information and communication technologies module

The information and communication technologies (ICT) module aims to provide a proposal for training and research in ICT and telecommunications, and to design, to plan and to develop projects related to the use of low-cost ICTs in order to contribute to the development of disadvantaged people. To do this, there are:

- Computer equipment: 2 laptops for training and 2 more for the work team, 9 workstations, 5 spares of network cards, 2 spares of laptop batteries, and a color printer.
- Multimedia equipment: two multimedia projectors, an interactive whiteboard to enhance trainings and an electronic screen with laser pointers.
- Telecommunication equipment: equipment that facilitates the development of workshops and courses in wireless networks (antennas, routers, wireless cards, etc.).
- Video-security system.

2.2.3 Water and sanitation module

The water and sanitation module has:

- Different models of bio-filters for the development of practical workshops.
- Break-pressures with PVC pipe.
- A dry ecological toilet, currently under construction.

3. Support to rural electrification projects

Access to information, training, work experience, transfer, business management strengthening is needed in order to to ensure that rural electrification projects are carried out with the right technology and can be self-sustaining from its initial design.

The CEDECAP began as a tool for the improvement of projects in social and technical aspects, to ensure the projects' effectiveness and their long-term sustainability. Nowadays, it still maintains this role, among others, and supports the implementation of projects at all stages: from the project identification and design (technical and social aspects) to the implementation and subsequent follow-up and performance monitoring:

1. Identification of the project: Presentation and explanation of the project to the authorities and the community members, in technical and social terms, to confirm their interest in it.
2. Training of the community: In technical terms (use of energy and proper functioning of the systems) and in social terms (rights and obligations of users of the systems).
3. Design of the management model: The scheme of organization that will be responsible of economic management and technical maintenance of the system is designed and decided jointly with the community.
4. Training of candidates to operator-administrator (Vilar et al, 2006): Candidates to be operators and administrators of the system receive a specialized training in technical and economic issues. In the end, the community elects two candidates to be an operator and an administrator, who will receive an extra course in order to strengthen their capabilities for running the systems.

5. Later follow-up and support in technical and social aspects: The CEDECAP team is responsible for supporting and monitoring technical and social projects, and to respond to specific queries.

3.1 Training and linkage with the operators-administrators

The training of some community members in the use and maintenance of the systems (operators) is a first step but, to ensure long-term sustainability, technological training is not enough. In order to keep the system running along its useful lifetime, it is also necessary to develop technical and economic management systems (Figure 1) that make possible to face up with the costs of repairs and periodic replacement of components (preventive maintenance). In this regard, some classical trainings that omitted management issues, have erroneously led the community to think that the systems work by themselves, without creating the awareness of the need to manage sustainably.

In general, beneficiaries of projects and CEDECAP users come from communal practice and reinforce their knowledge to provide a suitable service to their community. Generally, their community would not have electricity in the short and medium term, except by the renewable energy projects. Some farmers have had experience of other projects of Practical Action and are beneficiaries of water training programs, among others. They look for increasing their qualification to specialize in maintenance and operation of renewable energy techniques. Thus, they are involved from the beginning in the process of research and socio-economic diagnosis to establish the access mode to energy. Together with the technical team and the community, they are responsible of the selection of the users to electrify. This implies that the user must have family at scholar age and have participated in the previous processes (meetings, community work), in recognition of its counterpart.

To select a promoter or administrator, the first stage is to call for a meeting with all the community. In each community, eight people are formed to be promoters and administrators through a three to four days training in the CEDECAP, where they learn the operation and management of the renewable technologies to be implemented in the community. In order to improve the selection process, the technical team organizes a mini competition to select the best pairs of administrators and/or technicians basing on work plans presentations. The evaluator committee selects the best couple (operator and administrator), trying to make interdisciplinary teams. Then, the couple receives strengthening capabilities program for the appropriate operation and maintenance of the generating machines and the microgrids.

The installed electrification system passes through a stage of validation. This implies technical support to the facilities and the operators' decisions; this technical assistance helps to correct the problems promptly. However, despite the support, some systems may have different technical difficulties during the pilot test; these situations are in most cases promptly and progressively corrected. The technical support of the project team does not avoid that some operators seek support from other specialists, for example, the leading power generation and energy trading. This aspect is positive because it reflects the interest of the operator to expand his expertise in order to maintain the system properly. In most cases, when the system "reaches the operating point" the operator has already acquired capacities to maintain the system.

3.2 Training and participation of the community beneficiaries

All the community receive training on the mechanisms of installation and maintenance of home systems. Users were trained on both technical and administrative topics, how to operate the household equipment, read the controller, manage battery charging and understand the tariff and late fees. The training program include 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 take place at the school and the practice is undertaken during the installation of the systems. The implementation of the management model is developed in parallel to the installation of the systems, and promete participation of the entire village. Moreover, many communities now require training to reinforce the one received during the execution of the project, which in fact should always be included in post or impact assessments. Therefore, one of the useful or indispensable tools to ensure sustainability in the medium and long term of the technology-based development programs are Regional Training Centers, to offer continued support to the projects. Additionally, operators have played an important role in promoting the proper use of energy, going door to door to explain the residents the proper use of the systems from the in-door wiring to the mechanisms of saving electricity.

Communities lighting usually consists of two or three 15W bulbs and for some families a TV and a DVD player. In some areas not reached by the broadcast TV signal there are also satellite dishes. The energy is used to charge cell phones and even to sell the cell phone charging service to users from other communities who have not energy yet. The CEDECAP has developed complementary and transversal learning on the use and saving of domiciliary electric energy. This issue usually does not receive enough attention by the beneficiaries, as part of the training to the access to electricity. However, in micro hydroelectric facilities where there is normally an excess of energy during the day, people are encouraged to seek new commercial outlets and small businesses by a proportionally lowering rate when increasing consumption.

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 (Figure 6). 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. Finally, gender perspective is an institutional policy and has to be taken into account when formulating and implementing projects. In practical terms, gender perspective allows access to project benefits to a greater number of women, since the existence of gender inequities in rural areas is admitted and considered from the beginning. With this objective, organizations led by women are sought to identify their advances on promoting gender equality in the area. In particular, participation of women in trainings was promoted and monitored to ensure their appropriation of the technology and the project.

Fig. 6. Training of operators in the CEDECAP

4. Capacity development program

In this section, the capacity development program of the CEDECAP is presented in terms of the offered courses, used pedagogical methodologies and their involvement in education programs. Finally, a summary of the realized activities is provided.

4.1 Training proposal

The CEDECAP has developed training activities especially designed to meet evident demands at different levels: universities, municipalities, regional governments, technicians, specialists and manufacturers have improved and increased their knowledge. Moreover, these events answer to local, regional and international demands. Table 1 shows the main types of scheduled training activities:

ACTIVITY	INTRODUCTION	OBJECTIVES
WORKSHOP TRAINING FOR RURAL ENERGY DEVELOPERS Target audience: rural promoters.	Traditionally, in the scenario of energy development work in rural areas, farmers, who are the main players, have been excluded from the processes of searching alternatives and even from the implementation of technologies and knowledge aimed to solve their own problems. Rural development requires a process of rapprochement between professionals, technicians and farmers, which achieves on solutions to the problems of communities, developing and strengthening local capacities. This workshop aims to complement the training of rural promoters, adding the energy component as one of the main inputs for the promotion of development in their environment.	To develop and strengthen capacities of rural promoters in order to improve their technical and social skills in the field of local development, and to become rural energy developers.
WORKSHOP POLICIES AND ENERGY DEVELOPMENT Target audience: leaders, authorities, officials and decision makers.	The analysis, reflection and implementation of energy policies in the field of rural electrification should be part of the ongoing tasks of the leaders and institutions that make decisions to improve access to electricity and to promote local economic development. This workshop aims to disseminate experiences and to generate the discussion on electrification policies in the country and its implications for regional and local energy development. It also aims to promote the interrelationship of both public and private institutions in the field of rural electrification.	To promote discusses and analysis of the rural electrification problems. To motivate synergies between the institutions and other actors to strengthen the work on rural electrification.
COURSE MANAGEMENT, OPERATION AND MAINTENANCE OF MICRO-HYDROELECTRIC POWER PLANTS Target audience: managers and operators of energy systems.	Micro hydro energy is a suitable option for isolated rural areas that have courses and waterfalls, which enables them to access to basic energy services and to improve their living conditions. To ensure the success and sustainability, these projects require, the proper implementation of the technology to the efficient use of water resources, and the development of a set of tools for the management, operation and maintenance of systems. These tools must ensure the quality and continuity of the energy service, as well as the lifespan of equipment and its accessories, using local human resources as the main support for system's sustainability. This course aims strengthen knowledge of operators and managers of small hydroelectric systems, both in technical and organizational and administrative aspects, which will improve their performance.	To transmit theoretical and practical knowledge to develop the capacities of operators and managers of micro hydroelectric power plants for identifying and resolving performance problems in those facilities, identifying and using proper tools for a good management, service control and decision-making.

ACTIVITY	INTRODUCTION	OBJECTIVES
COURSE ASSESSMENT, DESIGN AND MANAGEMENT OF WIND, PHOTOVOLTAIC AND HYDRAULIC LOW-POWER SYSTEMS Target audience: students in the last cycles of technical levels and academics.	In technical degrees, students are formed about large-scale facilities implementation of renewable energies. Furthermore, in most cases, education is theoretical. This course aims to complement the education given in these degrees by providing to students a very practical course about low-power energy systems for rural electrification.	To strengthen academic training is taking place in the higher level centers of the country through the creation of new knowledge and abilities in young students, so they can harness the potential of renewable energies in the country.
INTERNATIONAL COURSE SPECIALIZATION ON MICRO HYDROENERGY, WIND AND PHOTOVOLTAIC SYSTEMS Target audience: technical specialists and researchers, employees and technical staff from public administration and students of the last cycles of technical levels and academics.	Technologies based on the use of renewable energies have proven to be adequate for the electrification of isolated rural communities with autonomous systems. In this context, improvements on the systems are being developed to increase its potential, both technically and in the intervention methodologies. This course offers a specific training in the latest advances of these technologies and creates a space for discussion and experiences exchange, for those involved in the implementation of these systems, counting on professionals and institutions of international prestige.	Strengthen capacities for planning, policies implementation and rural electrification projects of government employees, professionals, technicians and researchers in isolated electrical power generation through renewable energies, in order to show evidences of advances in developed technological and experiences on the use of renewable energies.
VIRTUAL COURSE ENERGY AND COOPERATION FOR DEVELOPMENT Target audience: designers and project managers.	In the framework of cooperation for development, energy supply for the implementation of projects is usually seen as a tool to generate energy. This approach ignores the role of access to energy for achieving the Millennium Development Goals of the UN (PNUD, 2005a,b) and, consequently, the different dimensions of energy as a technology for human development are not considered. This course aims to make understand energy and energy technologies as a transversal approach to projects, to promote sustainable and human development as a tool of social transformation of the beneficiary communities.	To identify and to discuss strategies, programs and projects that include energy supply for domestically, communal or productive uses. To analyze energy as a tool of social transformation from the point of view of sustainable and human development.

Table 1. Main courses scheduled in the CEDECAP

So far courses and workshops offered by CEDECAP have achieved that:

- Students, especially of engineering careers, improve their academic skills and receive new technical and social knowledge.
- Peasant leaders are aware of the natural resources that can be used to promote rural electrification projects. This in turn allows a greater field of negotiation of the leaders with the political authorities that implement strategies at regional and national levels.
- Technicians and professionals refine and expand their expertise and broaden their knowledge in cross issues to their own disciplines, thus allowing professional skills to become more versatile.
- Manufacturers and designers exchange experiences and knowledge about elaboration process, which enables to work respecting technical standards.
- Authorities and politicians are aware of the characteristics of energy demands in rural communities and are able to set some criteria to look for a better implementation of energy policies.

Figure 7 shows some examples of trainings in the different technologies in the CEDECAP facilities.

Fig. 7. Examples of trainings in micro hydro (left), wind (center) and PV (right) technologies

4.2 Teaching methodology

Although the methodologies used in the areas of training have been diverse, one aspect has been a common priority: the practice. In this sense, one of the most noteworthy aspects of CEDECAP is the availability of real size facilities. Thus, practice lessons were carried out in installations equal to real systems, students could learn exactly how it worked, and how they should be operated once installed in the communities.

CEDECAP's formative approach is based on the concept of "constructivist learning". This approach includes the need of the analysis, the representation and the management of contents and exercises to transmit in a proper, reliable and organized manner. For that reason, the educational methods must be adapted to the sociocultural context of the students. In other words, it is a perspective of training as a way to strengthen the abilities and skills of people and to develop guidelines for strengthening competences. This approach is defined in relation to social actors that it expects to train. Therefore, the beginning is the knowledge of each person.

Extending the range of courses implied improving the courses and trainings from a pedagogic point of view. Training teachers in pedagogic techniques in order to achieve better results in the target population was a challenge. In this sense, the role of an educational consultant for the implementation of courses was essential to make the corresponding improvements. Currently, there are educational records of all courses in which objectives, contents, skills and learning expectations are clarified.

4.3 Formal education

The development of a competency-based curriculum permitted to link the CEDECAP with formal technical training programs, which now is the main challenge for the future impact and sustainability of the center. The idea was to keep the system and the practical experience alive while developing formal educational organizations (professional training centers, universities) that allow to certify the skills acquired by the students. In this sense, the most notorious result has been the relation of the CEDECAP and the CEFOP, an agricultural training center in Cajamarca. In this regard, in 2008, a cooperation agreement with Fe y Alegría (CEFOP), an organization with the same objective of developing capacities of vulnerable people from rural areas, was signed to contribute to the institutionalization of training activities. Thanks to the alliance with CEDECAP, the possible use of renewable energy for improving production, handling and processing of products has been inserted in the courses of CEFOP.

The CEFOP has been working in Cajamarca since 1998; the work began with a European Union project copying a successful Spanish model that trains and links young people who cannot follow a technical career by themselves. In Cajamarca, there is the vocation to productive livestock activities; as CEFOP centers respond to this productive vocation of each region, their specialties are related to this field. Young people are formed around the labor needs of each region, and besides, the formation of micro and small enterprises is promoted. In 2002, Fe y Alegría assumed CEFOP's management, according to an agreement that defines the management and CEFOP centers coverage expansion nationwide.

The CEFOP identifies three training milestones: first Productive Technician (1 year of training and graduates at the level of a qualified operator), second Higher Technician (2 years of training) and third Professional Technician (3 years of training). The feature of this training is that a young person that studies for professional technician, receives the same training modules that a higher or productive technician. Until 2007, the CEFOP had the same level as a CETPRO, but later, the development of higher technological education was authorized. According to the teachers and directives, CEFOP's methodology ensures a very practical training, where 70% of time is in field or expertise and 30% in classroom. In this sense, the training methodology starts from the formulation of a productive project, and depending on the needs of the project, young people are trained. This training methodology is being developed in the different organizations where the CEFOP takes part.

The new training modules were worked together with teachers and technical staffs, under the capacities focus. The design of the modules was born from the experience of Practical Action in the field of renewable energies and the Universitat Politècnica de Catalunya for the methodological development of new proposals. This, together with the technical support of human resources from the CEFOP, is a good basis for learning. The construction of the training modules has been developed from workshops realized in the CEFOP, both among the involved organizations and the participation of specialists. The students prepare for the agricultural part but are cross-trained in renewable energies (an average of 10% of all the training in a year).

When developing renewable energies modules, Practical Action's technical team participated getting involved as specialist teachers in different subjects. Students have done training to do the maintenance and the conceptual development. Practical lessons were carried out in the CEDECAP’s facilities. The courses were conducted with the active participation of students, and at the end of the training, they were able to install or maintain an energy provision system. Another prominent theme of working together has been the construction and operation of a bio-digester in the CEFOP. In this line, the program covered from the background knowledge to the installation of the bio-digester, as well as identified the capacities and abilities for the installation of this tool. This work was carried out under the coordination between students and CEFOP teachers.

4.4 Summary of the realized activities

Since 2005 until today, the CEDECAP has allowed the development of many training activities:

- 22 courses have been developed on the subject matter of renewable energies, rural strategic planning and implementation of bio-digesters. 484 people have participated in the courses, among subnational government employees, students and renewable energies promoters. The courses are:
  - 3 international courses and 1 virtual course on renewable energies.
  - 18 regional courses and workshops related to renewable energies.
  - 15 workshops and internships on rural electrification planning.
  - 5 workshops on bio-digesters.
- 22 educational materials have been generated for training programs. These are:
  - 9 presentations.
  - 1 training report.
  - 9 hand-outs.
  - 3 user’s manual.
- The CEDECAP supports the electrification projects of Practical Action. For example, since 2005, 5 hydroelectric projects and 3 wind projects have been implemented.

5. Research and development

The CEDECAP has real-size facilities that are used both for training and for research purposes. It is especially relevant that real-size equipment allow very applied and practical research. Moreover, improvements and technical developments can be tested in the CEDECAP before moving on to real projects to ensure that their performance in field will be appropriate and reliable. Next, we present the main reach lines that have been developed involving wind electrification systems, household bio-digesters and methodologies for developing rural electrification plans.

5.1 Wind electrification systems

It is worth to mention the research carried out in relation to small wind turbines. 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. Wind turbines were designed under the concept of appropriate technology: they should be simple, cheap, reliable, easy to maintain and, above all, achievable through local workshops or microenterprises with a minimum of imported materials and components (Schumacher, 1973). In the case of Peru, the developed turbines were specifically designed to operate at low-moderate wind speeds that predominate in Andean Peru. In August 2006, a meeting between Practical Action (International Programs and Latin America's Office), Engineers Without Borders – Catalonia and the Universitat Politècnica de Catalunya (UPC) was celebrated in Cajamarca (Peru). At that meeting the three entities established and promoted the groundwork for the design of an international program called "Development and Dissemination of Micro Wind Energy Generation Systems in Developing Countries (Micro-WEGS)", whose main coordinator was Teodoro Sánchez, the technologies and policies consultant of Practical Action.

Until now, two different models have been developed: the IT-PE-100 operates with wind speeds from 3.5 m/s to 12 m/s, and produces 100W at 6.5 m/s, and the SP-500 that produces 500W at 8 m/s. Both models are furling tail turbines with three fiberglass blades and axial permanent magnet generators. At the same time, a local company was created to manufacture the wind turbines in Lima, thereby stimulating business creation and facilitating repair and parts replacement. So far, these models have already been used in the electrification of three communities in Peru (Ferrer-Martí et al, 2010). Moreover, these designs and technology were transferred to Bolivia. A Peruvian team from Practical Action went to Bolivia to impart theoretical bases of the designs and how to manufacture them in NGOs (Prodener, CINER) and universities (Universidad de San Simon, Universidad de San Antonio Abad). In this sense, research studies continue to improve the mechanical aspects checking the design, materials and manufacturing processes to improve the general performance of the wind turbine from the queue system redesign and to improve its robustness against non-constant winds, trying to influence the vibration's control. In parallel, control systems are being developed to optimize generator's performance (Colet-Subirachs et al, 2010) and low-cost monitoring systems, to record and characterize the operation of all the equipment.

Moreover, some research studies are being developed for the optimization of the design of the projects, studying the location of the generators and the use of possible distribution microgrids. Due to the characteristic dispersion between households in the villages, the projects tend to install individual wind turbines at each demand point. However, the projects that combine individual generators and microgrids have proven to be beneficial: this design option considers the use of more powerful turbines, economically advantageous, and does not constraint the energy of a demand point to its location. The objective of these studies is to develop a decision models to design wind electrification projects, taking into account the location of the demand points, the detailed wind resource map and the possible use of micro grids. The wind resource at each point of the village is calculated using specialized software (Ferrer-Martí et al, submitted).

Mixed and integer linear programming (MILP) models have been developed to solve the design of the wind electrification project and gives the location and size or type of the wind turbines systems, the batteries, the charge controllers, the inverters, and the wires to be used in the micro grids (Ferrer-Martí et al, 2011). This type of mathematical formulation is used to model combinatorial problems, and can be solved optimally using specialized software. As input data, we introduce the location, the energy, and the power demand of each point, as well as the detailed map of the wind and solar potential of the village and the costs and technical characteristics of the equipment. As constraints, we introduce the technical characteristics and relation between the generation, storage and distribution equipment. Moreover, social constraints to consider social characteristics of the village and to improve the performance of the system from a social point of view are also introduced. Recently, models have been extended to consider hybrid systems with wind and photovoltaic generators (Ranaboldo et al, submitted) and micro hydraulic systems.

5.2 Household bio-digesters

Another research line has studied the technological development and performance of household bio-digesters for the use of biogas in the kitchen and the use of biol as an organic fertilizer. Low-cost tubular digesters originally were developed in tropical regions; to work in Andean Plateau designs and operation conditions had to be adapted to the extreme weather conditions of 3000-4000 m above sea level, where average annual temperatures are around 10 ºC. Since 2006, more than 30 digesters have been implemented in rural Andean communities of Peru by means of pilot research and development cooperation projects. In these projects, improvements in the design, in the used materials and in the management process where introduced. Moreover, two bio-digesters have been put at the National Institute of Farming Research (INIA) to be able to control and evaluate the biogas production under controlled conditions.

The adaptation of low-cost plastic tubular digesters originally developed for tropical areas to the conditions of the Andean plateau, continues to be a technological challenge. In this sense, research involving the characterization of the performance and the development of adapted and optimized designs has been developed. This information is needed in order to evaluate the performance of the systems, improve their efficiency and reduce capital costs, which would help fulfilling the strong demand for low-cost digesters by families and farmers in the Andes.

First, studies involving the analysis of biogas in such conditions were carried out to characterize the production, its composition and the burners' efficiency (Ferrer et al, 2011). To this end, two pilot plants were monitored and field campaigns were carried out in two representative household digesters of rural communities. In this study, we verified that specific biogas production in household digesters designed for extreme conditions of Andean communities was relatively low in comparison with digesters implemented in tropical areas, but methane content in biogas was high and a maximum burner's efficiency was around 52%. Currently, the biogas produced in household digesters is consumed during 2-3 h of cooking per day, depending on the location, weather and operation conditions. This accounts for 40-60 % of fuel requirements for cooking.

First, we study the anaerobic digestion of guinea pig manure alone in low-cost unheated tubular digesters, as guinea pig is one of the most common livestock in rural communities of the Andes (Garfi et al, 2011). Two greenhouse designs were compared: in the dome roof digester the temperature and biogas production were significantly higher than in the shed roof digester. In a preliminary fertilization study, the potato yield per hectare was increased by 100% using the effluent as bio-fertilizer. However, the biogas production rate was low, which is attributed to the low organic loading rate, so results recommend to improve manure management techniques, increasing the organic loading rate and co-digesting other substrates to enhance the process. Taking into account the low biogas potential of cow manure compared to other cattle dung, next studies analyses if the process was enhanced by co-digestion with other manure and food or vegetable wastes. Moreover, agricultural reuse of the digestate from low-cost tubular digesters as fertilizer is being analyzed (Garfi et al, in press).

6. Information and advocacy node

CEDECAP aims to become a reference node in the Andean region in training in rural electrification and in the rational and efficient use of energy, in terms of disseminating information and promoting networking.

6.1 Information center

The CEDECAP has a library, which has technical documents about non-conventional energies and all the material generated in the events and training processes. Recently, the website has been updated to provide technical consulting service in addition to supplying information (documents, papers, reports). CEDECAP's website is independent from Practical Action's website, and until December 2009, 650 people had visited it. However, the website does not allow the user to connect directly to a specialist, but only indirectly.

The international courses on projects and systems design are a meeting place for NGOs, universities (students and teachers) and professional technicians. In addition, workshops that are organized around specific themes are the meeting point for civil society, universities, administration, private sector and government. In this sense, conversations with OLADE (Ecuador), that has 26 countries as partners, were initiated. Together with the organization, a virtual international course in micro hydroelectric power plants (both technical and management) was made using the OLADE platform. The alliance with OLADE allowed the groups to count on support to find demand in Latin America. Virtual courses are taken by OLADE as a success because the interesting and virtually forced subject reaches to 26 countries. For the CEDECAP the link is valuable because the institution has been recognized as a visible organization with expertise in the field of renewable energies. In particular, developing courses in a virtual platform (OLADE, 2008) allows not only training people from very different geographical areas, but also providing opportunities for participatory group learning with people of different cultures and personal and professional experiences.

6.2 Networking center

Promoting the CEDECAP means trying to promote networking, social connectivity, exchange and interaction between different actors involved in sustainable development in the region. Moreover, among the innovative aspects of CEDECAP, it is worth to mention the opportunity to break the paradigm that technology transfer is always from north to south. This project strengthens and promotes South-North and South-South transfers. In this sense, the center aims to create new spaces to canalize and share knowledge, and create new synergies between different actors in the public or private development, both South and North.

The formation of these knowledge networks, which will be promoted with greater emphasis on Latin American countries, will shape new ideas and proposals that contribute to reduce the gap of isolation between academicals, governmental, NGO and private institutions. Strengthening the approach between these institutions will result in, among others, the opportunity to influence public policies related to the technical proposal of the center.

In particular, the CEDECAP is the permanent headquarters of the technical secretariat of the Latin American Network of Hydro energy (HIDRORED), whose framework is the use of renewable energy in rural areas. HIDRORED is made up of public and private organizations, mostly universities, development cooperation organizations and centers that promote renewable energy in Latin America and Europe. The magazines HIDRORED and Energía y Desarrollo offer an information service about the experiences and activities of the organizations working in the field of energy and development. Currently, there is an extensive broadcast coverage: around 50 countries receive the editions of the magazines.

Among the events organized and held in the CEDECAP, for example, must be highlighted the XIII Latin American and Caribbean Meeting on small hydropower exploitation that took place between 20 and 24 July 2009. The event was organized by the Latin American Network of Energy (Hidrored), Practical Action – ITDG, Engineers Without Borders (ESF) and Green Empowerment (GE). The event was divided into 3 parts: 1) a course on evaluation, design, implementation and management of small-scale wind energy systems; 2) a conference including specialists, professionals, researchers and interested persons from Latin America; and 3) a meeting of the Latin American Network Hidrored. The target audience was: researchers and professionals interested on spreading their progress and experiences, officials of non-governmental institutions related to the implementation of PAH in Latin America and the Caribbean, officials of financial institutions, international cooperation agencies, multilateral development agencies, equipment manufacturers, contractors and consultants.

7. Planning rural electrification systems

Recently, studies in developing procedures to improve the electrification systems with renewable energies in the broadest sense have been initiated: the development of rural electrification plans as a method for the diagnosis, selection and implementation of projects. The conventional strategy for increasing access to electricity is extending the national electricity grid; however, this option is limited by the complex terrain and dispersed nature of rural villages in some regions. Under these circumstances, stand-alone electrification systems that use renewable energy sources are a suitable alternative. A methodology for evaluating and analyzing the energy needs and potentials is required in order to design a rural electrification plan where each community has its own stand-alone electrification system. Progress has been made on a methodology that: 1) encourages and involves the coordinated participation in all institutional and community levels; 2) obtains proposals of projects and the technological designs from the analysis and comprehensive studies that considers the needs and potentials of the people; and 3) considers and includes funding instruments to ensure that the plan successfully translates in implemented projects.

The isolated rural electrification is usually accomplished by means of individual photovoltaic systems- without assessing the demand, needs, energy potentialities or community's organization. This lack of evaluation criteria tends to lead to inadequate solutions that do not meet demand, that install generators in non-priority sites, or that are technologically inappropriate. The omission of these factors implies the risk that the community will not appropriate itself the system, which would lead to inadequate management and maintenance. Consequently, many projects stop working in a few years due to technical or management problems. In most cases, standard solutions are not suitable and the appropriate design of the solutions, unlike what is normally considered, is not simple or easy. Furthermore, in isolated systems that do not have the flexibility to absorb new users or possible changes in the demand or in the demand profile, thus, a detailed project design is even more necessary in order to cover these aspects. In this sense, planning is essential to ensure the appropriate design of these autonomous projects.

It is important to define what Rural Electrification Plan using Renewable Energies means. It is a process aiming to identify needs and energy potentialities from a geographic area, which is not included in the rural electrification plan of the country or a regional government. Furthermore, domestic and productive demand can be met through appropriate technologies at local and regional levels. It is noteworthy that this process is not independent or isolated, but aims to strengthen the work done by the regional energy agencies, providing real information and promoting internal dynamics that may be useful for a more harmonious development of the national energetic sector.

The methodology to implement a plan should consider the particularities of the electrification systems of each of the communities included in the plan. In particular, a rural electrification plan of isolated systems should: 1) encourage and involve the coordinated participation in all institutional and community levels, 2) obtain project proposals from complete analysis and studies that consider needs and potentials of people, and 3) consider and include funding mechanisms that ensure the plan runs successfully, translating in implemented projects. With this information, the CEDECAP coordinates with authorities such as the Ministry of Energy and Mines trying to link them to the energy access proposal from the population.

Thus, the first experiment in regional or local energy planning was carried out in the region of Cajamarca, province of San Pablo, where the rural electrification rate has increased from 13.6 to 19% in the period from 2007 to 2009, although it still remains one of the lowest of Peru [HDR, 2009]. The process lasted 10 months, and the projects portfolio was obtained and made funding search possible, both internally (FONCOMUN, Canon) and externally (international cooperation and regional government). The REP of San Pablo cost $ 4000 and allowed to engage municipalities to invest S/. 4000000 (a quarter has already been spent on the development of isolated rural electrification projects). It is noteworthy the participation of district municipalities with their technical teams throughout the development of the plan, as well as community participation, since they are the ones who will ultimately be present at the implementation of the system. Currently, the CEDECAP has the strategy of working with local governments for making an energy planning in each of the districts jointly.

Due to lack of references, CEDECAP's technical team is working to adapt the public investment system to project profiles in renewable energies. Mechanisms and guidelines have been created to support municipalities in the formulation of investment projects; the main idea is to save administrative processes. This guidance will also be delivered to the regional government presidency.

8. Conclusions

Electrification systems based on the use of renewable energy sources are suitable for providing electricity to isolated communities autonomously. However, there are barriers that hinder this process and, between them, the major one is lack of local capacities. In this context, Practical Action (Peru), Engineers Without Borders (Spain), Universitat Politècnica de Catalunya (Spain) and Green Empowerment (USA) are promoting the CEDECAP, a capacity development center in Peru that support the implementation of energy projects and trains farmers, community leaders, policy makers and students of technical degrees and universities. In 2006-2009, 22 courses were developed with 484 participants and 22 educational materials.

The future challenge of CEDECAP is to strengthen and to consolidate its role within formal education, both in professional schools and universities, to increase professional's training, upgrade research and keep on working to insert renewable energy projects on the political agenda as a definitive step for promoting and improving their impact.

9. Acknowledgments

This paper was supported by the Spanish MICINN project ENE2010-15509 and co-financed by FEDER, the Centre of Cooperation for Development of the Universitat Politècnica de Catalunya (UPC), the Agència Catalana de Cooperació al Desenvolupament (ACCD), the Generalitat de Catalunya, the Ajuntament de Barcelona, the Agencia Española de Cooperación Internacional para el Desarrollo and the Directoraten-Generaal Internationale Samenwerking (DGIS).

10. References

Bouille, D. and McDade, S. (2002). Capacity for development. Energy for Sustainable Development. A policy agenda. Johansson and Goldemberg (eds.). UN Development Programme. New York.

Chaureya, A., Ranganathana, M. and Mohanty, P. (2004). Electricity access for geographically disadvantaged rural communities—technology and policy insights. Energy Policy, 32, 1693–1705.

Colet-Subirachs, A., Gomis-Bellmunt, O., Clos-Costa, D., Martín- Segura, G., Junyent Ferre, A., Villafáfila-Robles. R. and Ferrer-Martí, L. (2010). Electromechanical modelling and control of a micro-wind generation system for isolated low power DC micro grids. EPE Journal, 20 (2), 2943-2959.

Fernández-Baldor, A., Hueso, A. and Boni, A. (2009). Technologies for Freedom: collective agency-oriented technology for development processes. Annual Conference of Human Development and Capability Association at the Pontificia Universidad Católica del Perú.

Ferrer, I., Garfi, M., Uggetti, E., Ferrer-Martí, L., Calderon, A. and Velo, E. (2011). Biogas production in low-cost household digesters at the Peruvian Andes. Biomass & Bioenergy, 35 (5), 1668-1674.

Ferrer-Martí, L., Garwood, A., Chiroque, J., Escobar, R., Coello, J. and Castro, M. (2010). A community small-scale wind generation project in Peru. Wind Engineering. Special Issue on Small Wind Energy for Developing Countries, 277-288.

Ferrer-Martí, L., Pastor, R., Capó, G.M. and Velo, E. (2011). Optimizing microwind rural electrification projects. A case study in Peru. Journal of Global Optimization, 50 (1), 127-143.

Ferrer-Martí, L., Domenech, B., García-Villoria, A. and Pastor, R. A MILP model to design hybrid-photovoltaic isolated rural electrification projects in developing countries. European Journal of Operational Research (Submitted).

Garfí, M., Ferrer-Martí, L., Villegas, V. and Ferrer, I. (2011). Psychrophilic anaerobic digestion of guinea pig manure in low-cost tubular digesters at high altitude. Bioresource Technology, 102 (10), 6356-6359.

Garfí, M., Gelman, P., Comas, J. and Ferrer, I. Agricultural reuse of the digestate from low-cost tubular digesters in rural Andean communities. Waste Management, (in press).

Modi, V., McDade, S., Lallement, D. and Saghir, J. (2006). Energy and the Millennium Development Goals. New York: Energy Sector Management Assistance Programme, United Nations Development Program.

OLADE Latin American Organization of Energy (2008). Diseño, implementación y gestión de microcentrales hidroeléctricas. From 6 to 29 october 2008 at the IMTA (Instituo Mexicano de Tecnología del Agua), Mexico. Available at: http://www.imta.gob.mx/index.php?option=com_content&view=article&id=260 &Itemid=90

PNUD (2005a). Achieving MDG: the role of energy services.

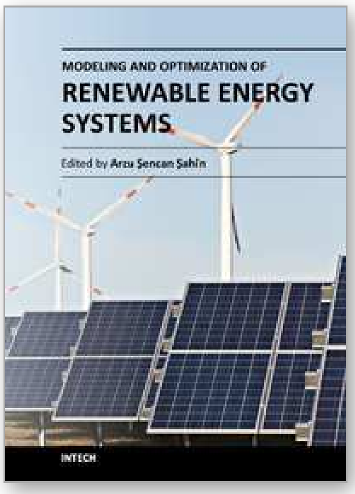
PNUD-ESMAP (2005b). Energy Services for the Millenium Development Goals. UNDP, UN Millennium Project, World Bank, and ESMAP. New York.

Ranaboldo, M., Ferrer-Martí, L. and Velo, E. Micro-scale wind resource assessment for off-grid electrification projects in rural communities. A case study in Peru. Int. Journal of Green Energy (Submitted).

Schumacher, E.F. (1973). Small is beautiful: Economics as if people mattered. Blond & Briggs, London, UK.

Vilar, D., Sneij, J., Marcelo, O. and Martín, G. (2006). Developing peasants' capacity on the operation and maintenance of a photovoltaic system. Experience in a training centre of the Andean region. 21st European Photovoltaic Energy Conference and Exhibition.

World Health Organization (WHO), United Nations Development Programme (UNDP) (2009). The energy access situation in developing countries. Available at [last accessed 3 December, 2010]: http://www.who.int/indoorair/publications/energyaccesssituation/en/index.html.



Modeling and Optimization of Renewable Energy Systems

Edited by Dr. Arzu Şencan

ISBN 978-953-51-0600-5

Hard cover, 298 pages

Publisher InTech

Published online 11, May, 2012

Published in print edition May, 2012

This book includes solar energy, wind energy, hybrid systems, biofuels, energy management and efficiency, optimization of renewable energy systems and much more. Subsequently, the book presents the physical and technical principles of promising ways of utilizing renewable energies. The authors provide the important data and parameter sets for the major possibilities of renewable energies utilization which allow an economic and environmental assessment. Such an assessment enables us to judge the chances and limits of the multiple options utilizing renewable energy sources. It will provide useful insights in the modeling and optimization of different renewable systems. The primary target audience for the book includes students, researchers, and people working on renewable energy systems.

INTECH
open science | open minds

InTech Europe
University Campus STeP Ri
Slavka Krautzeka 83/A
51000 Rijeka, Croatia
Phone: +385 (51) 770 447
Fax: +385 (51) 686 166
www.intechopen.com

InTech China
Unit 405, Office Block, Hotel Equatorial Shanghai
No.65, Yan An Road (West), Shanghai, 200040, China
中国上海市延安西路65号上海国际贵都大饭店办公楼405单元
Phone: +86-21-62489820
Fax: +86-21-62489821