PICO HYDRO TURBINES FOR ELECTRICITY IN RURAL AREAS

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Theoretical training course
Source: Électriciens sans frontières

Électriciens sans frontières, a public interest international solidarity NGO, conducts electricity and water access projects to ensure the poorest populations in the world can enjoy sustainable access to energy that is reliable, affordable and as clean as possible. The skills and involvement of our 1,200 volunteers are harnessed to improve the living conditions of communities that are often rural and isolated.

KEYWORDS

- LAOS
- HYDROELECTRICITY
- PICO HYDRO TURBINE
- ELECTRIFICATION
- DEVELOPMENT

This article discusses the feedback and lessons learned, particularly from a survey carried out following the deployment program of a pico hydro power solution in a very isolated rural area in north Laos. This project is part of the strategic development for the rural electrification of Laos, in which pico hydro power facilities constitute the main avenue of progress for the electrification of isolated villages.

INTRODUCTION

Almost half the world's 1.2 billion people with no access to electricity live in South Asia (World Bank, 2013).

For the region, the consequences of this lack of access to clean, reliable energy are many and harmful. The absence of electricity is depriving the population of access to care and proper education conditions. It was observed that the rate of infant and maternal mortality drops with the rise of access to electricity (UNDP, 2009). Similarly, 50 per cent of primary schools in South Asia have no access to electricity, which affects the learning conditions of nearly 100 million students (Practical Action, 2014).

According to the context, the solutions are varied and assume different forms in urban areas, peri-urban areas, densely-populated rural areas or isolated rural areas. Beyond this first factor, adapting a solution to the local geographic, economic and social conditions is paramount. There is no single solution then, but a range of solutions to be applied depending on the situation.

In north Laos, many villages have no access to electricity. The population's dispersion and low density in this extremely rugged area make it unfeasible to consider expanding the national electricity grid. However, in Phôngsaly province, the local authorities identified the development of hydro power production as a strategic avenue of progress. They then appealed to Électriciens sans frontières to implement a deployment program of a pico hydro power solution.

1. GENESIS AND LOCAL CONTEXT OF THE PROJECT IN PHÔNGSALY PROVINCE IN 2006

Électriciens sans frontières has been present in Laos since 2003. In 2007, at the request of the provincial authorities, the NGO worked in partnership with the Comité de Développement Vietnam France (CODEV Vietphap) and EEP Mekong (Finnish cooperation) charities for the first time in Phôngsaly province, in the Nhot Ou and Phôngsaly districts. Originally the request focused on raising awareness of the villagers of electrical hazards and the transfer of competencies in the field of hydro power.

At the start of the project, Phôngsaly province had the lowest electrification rate in Laos, with only 13% households connected (Asian Development Bank, 2009).

The characteristics of this rugged area, which has many streams and rivers, is subject to monsoons and often covered in mists or fog, makes it natural to harness its potential for production of hydroelectric power. Thus the last decade has seen the emergence of the individual production of electricity using pico hydro turbines supplied by China. This production of electricity nevertheless remains quite random during monsoon flooding season, when keeping the pico hydro turbines in the water is difficult if not downright impossible.

In addition, only a very limited number of villagers are equipped with run of the river horizontal pico hydro turbines (0.3 to 0.6 kVA) placed in the watercourses near the villages. These few pico hydro turbines are installed in a very basic way by the villagers themselves. No installation has a voltage limiter and the lines, whose length is too often excessive, and poorly dimensioned and strongly degrade turbine electrical performance. The facilities are also often poorly protected and electrical accidents are therefore frequent.

In the face of this situation, the authorities and the Ministry of Energy (Electricity department) have informed us that the Électriciens sans frontières project was part of the strategic development for the rural electrification of Laos and that individual or collective pico hydro facilities represent the main avenue of progress for the electrification of isolated villages in Phôngsaly province.

The Lao Government also encourages all initiatives to reduce the poverty of the minorities in north Laos. Under this heading, Phôngsaly province has priority as regards national and international aid, and it has been the target of several programs of the European Union. The villages number 20 to 50 families on average from 30 different ethnic groups. One of the main sources of revenue (34% of revenue) is farming, with flocks composed 55% of chickens, 24% of pigs, and 7% of cattle. The second source of livelihood for the households is the sale of forest products not derived from wood (27%), followed by the planting of cereals (8%) and income from farm work (7%). The average annual income per household is USD 1,400, the lowest income being approximately USD 700 per annum. 94% of households lie below the poverty threshold set by national authorities (Coordination Sud, 2015).

After analyzing their expectations, we suggested the representatives of the provincial authorities accompany the rural populations of the province in a collective approach to access electricity. This approach is based primarily on the transfer of skills, through practical teaching sites and theoretical classes on the management of the resource and the control of electrical hazards, for 2 to 3 villagers selected by the local authorities on the basis of criteria set by Électriciens sans frontières. The selection criteria are relatively simple: young people with reading, writing and basic math skills, but mainly with spare time and an interest in the project.

WHAT IS A PICO HYDRO TURBINE?

1,000W pico hydro turbine
Source: Électriciens sans frontières

A pico-turbine is an assembly comprising a hydraulic turbine or propeller and a 220V single-phase alternator with a permanent magnet. The word "Pico" indicates the alternator's range of power. There are three types of hydraulic turbine: Run of the river Kaplan (vertical pico hydro turbine) or Francis turbine (horizontal pico hydro turbine), and Pelton waterwheel for the high heads ("seated" pico hydro turbine).

2. PRESENTATION AND ORGANIZATION OF PROJECTS ROLLED OUT BETWEEN 2007 AND 2012

The essential goal of these projects was to develop the villagers' capabilities to give them long-term, independent and safe collective access to electricity, relying on hydro power. The area concerned remained fairly localized, and if the operation could not be considered a large-scale rural electrification program, it was intended to reach out to several thousand beneficiaries and serve local authorities as a model for subsequent programs.

The approach therefore relied largely on a learning process intended to develop a sufficient mastery of technical operations and reflexes adapted specifically to pico hydro turbine technology. The

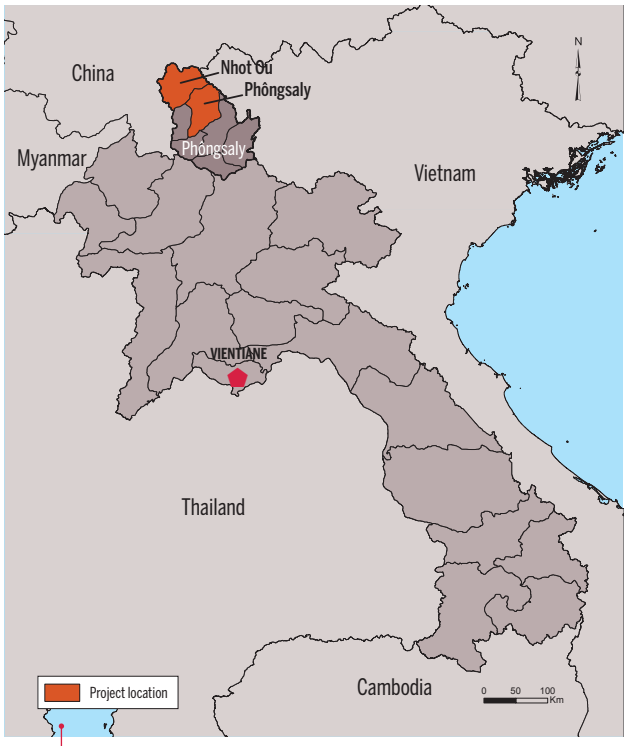

Figure 1. Project location - Source: FERDI

other component was to support the creation of a suitable organization and a favorable environment for the financial sustainability of the facilities (acceptability of fees, establishment of recognized management committees). Finally, all the actions carried out in this framework have been designed to ensure that everything that was transmitted or built could subsequently be reproduced.

Two districts were chosen for this action: Nhot Ou during 2007-2009, and Phôngsaly in 2009-2012. The operation concerned thirty-six villages. These villages were very isolated and excluded from any electrical distribution grid.

2.1. ECONOMIC MODEL AND ORGANIZATION

The project also promoted a collective approach to access electricity. The number of production sites being limited in the area, the solution was inevitably to share production, the rate ultimately retained being 1,000 W per 10 families. The installed pico hydro turbines were chosen according to the watercourse's characteristics and the exact needs of the village, pico hydro turbines of 250, 500, 600, 1,000 and 1,500 W being used. Where it was impossible to electrify all homes, the village governance bodies (village Chief, council of wise men, women's association and a young people's representative) decided on which dwellings to electrify with priority after an iteration process with all villagers. Since the choice was not based on objective criteria, in the event of disagreement between villagers and governance bodies, new meetings could be held until a consensus was reached. The villagers would then have to continue these actions in order to ensure all families of each village can enjoy access to electricity. After making an assessment of the proposed sites as regards hydraulic quality and reliability, Électriciens sans frontières let the village authorities decide the location of the program's pico hydro turbines among those sites with sufficient hydraulic quality. The project revealed some situations where a conflict arose between individual and general interest: in some villages, some families had usurped the right of ownership of the potential production sites on the watercourse by the village. The local authorities successfully ruled on these land problems, sometimes after agreeing on a compensation for the families in question. Similarly, the management principles down to the level of the fees and technicians' salaries were discussed collectively during the project and approved by the villagers.

In all of the villages, the project thus sought to substitute a purely individual energy management by a collective approach.

The management model set up is based on the creation of a village management committee, formed by the village Chief, 3 technicians, a village wise man, a representative of the women and a representative of the young (or a second wise person). This committee is responsible for collecting the fees from the households and relies on the technicians that it pays to carry out the maintenance operations. The fees are collected monthly, and the frequency of maintenance operations is set during the technicians' training period. Any surplus fees are set aside in a fund that can be used to purchase spare parts as required, or to enable the extension of the facilities (additional turbines, etc.) in the long term.

The economic model chosen for this project concentrates the efforts of the initial operator (Électriciens sans frontières) and its partners on the initial investment, while the contribution of the beneficiaries is focused on operating expenses. Électriciens sans frontières and its partners supplied all the equipment and tools, the beneficiaries paying a flat rate fee for access to electricity, used to finance spare parts procurement and maintenance.

The rates were set at the outset, at the outcome of the discussions within the villages, at a single flat rate of LAK 2,000 per month. To justify this single amount, voltage limiters were installed in order to avoid over-consumption by some families.

In terms of organization, the project was conducted collaboratively. The skills were transmitted and shared through teaching sites. In return, the project team relied on the irrigation skills and experience of many rice farmers in the region to reduce the construction costs of the hydraulic structures. The villagers helped build the hydraulic structures, the power lines and supplied all the available raw materials necessary for the works.

At an institutional level, the local authorities showed a strong involvement in the electrification programs. They became aware that sustainability issues were the most important and that installed systems should be based on the principles of sustainability and reliability. This project thus made it possible to encourage a true local institutional movement in Laos vis-a-vis isolated rural electrification, which echoes at small-scale the regional findings of the World Bank evaluation of electricity access programs

(Independent Evaluation Group, 2015)[1]. The involvement of the authorities in favor of electrification is strong at all levels and creates a favorable context not observed on other continents.

The choice of the trainees, training base villages, and villages to install the equipment was done directly by the Ministry of Energy and Mines, while the Department of Energy Policy and Planning managed the information to the various participants in the province concerned with the project and ensured compliance with the commitments of the local authorities and beneficiaries acting as the project steering committee. It is therefore tempting to extrapolate to isolated rural electrification the findings of the above report (Independent Evaluation Group, 2015)[2].

2.2. PRACTICAL ASPECTS

Young people were trained in both in the theory and the practice of pico hydro turbine selection and installation. Each training course included learning about several solutions, through the building of hydraulic works, installation of pico hydro turbines, construction of the electrical lines and creation of interior facilities.

At the end of the project, each village had a team of trained technicians capable of replicating the solutions best suited to the local context to ensure that the entire population could benefit from electricity. A management committee was set up in each village to manage and ensure the sustainability of the facilities and equipment.

The acquisition of general theoretical knowledge and practices required a 10- to 12-day course for a group of 12 to 18 technicians. Each session was organized in a "pilot" village. It was intended to provide the keys to understand the operation and use of hydroelectric installation and the practical knowledge necessary to run new installations or refurbish existing ones. This learning phase required concrete actions in the field, as well as an awareness-raising phase on the use of electricity for the families in the pilot village.

The consolidation and evaluation of the technicians' acquired knowledge were based on a full practical exercise: the trained technicians had to install at least two turbines per village. The works were then inspected by Électriciens sans frontières and corrected if necessary by the technicians.

Maintenance operations of several levels were carried out. They were acquired during a twelve-day course taught jointly by Électriciens sans frontières and instructors of the Lao-German Technical School of Vientiane. The exercises included replacing bearings, rewinding the alternator, balancing the machine's rotating part, redoing all seals, lubrication, etc.

Introducing electricity imposed some constraints and changes in behavior, regarding electricity as a hazard, energy saving, and rigorous use and sustainability of the facility. This public awareness issue was also addressed in training.

A little over 90 people were finally taught the techniques to create the facilities and some 20 were taught how to maintain them. The underlying idea was for villages to pool their resources in terms of tools and skills. Of the 36 villages, only 2 were equipped in the presence of Électriciens sans frontières. For the remaining 34, the trained technicians carried out the equipment's installation alone.

Between 1 and 5 variable power pico turbines were installed in each village at a rate of 1,000W per 10 families.

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1 "South Asia can also largely eliminate its access (to electricity) deficit if it maintains the pace of new connections it implemented in recent years", p XIV.

2 "These experiences illustrate common underlying principles adapted by each country to its own institutional framework, broadly stated : adherence to a nationwide least-cost national access rollout plan using coordinated grid and off-grid delivery as appropriate to achieve universal access nationwide", p XIII.

Practical training: tests and measurements on an installed pico hydro turbine
Source: Électriciens sans frontières

3. PROJECT PROGRESS

One of the characteristics of the NGO Électriciens sans frontières is that it is formed by volunteers who work in field operations. Generally, the operations for this project were carried out by teams of 2 to 3 volunteers, depending on the workload, over 5 week periods. Overall 18 operations were required to complete this project, a total of approximately 1,600 man days.

For the teaching activities in these communities it was necessary to create the training materials, translate them into Lao and convey all equipment and tools to the village. On site, the presence of a good interpreter was paramount to ensure the quality of the discussions.

All operations were covered by an agreement with the authorities, who supplied a transport vehicle, where tracks were available, as well as a guide who was also the district's representative of the Ministry of Energy and Mines. Each operation began with a working meeting with the Chief of the district, in the course of which the project advancement and the program of activities for the current mission were laid out. All operations concluded with a meeting to report to the Chief of the district.

The Ministry of Energy and Mines personnel of the province and districts took part in the training, with a view to acquiring the specific know-who and subsequently being able to provide advice and assistance to the villagers. In the framework of the project, Électriciens sans frontières equipped a small mechanical workshop in the premises Phôngsaly district.

In the villages, the volunteers were housed and fed by the population against payment, in view of the villagers' modest financial position. The contact in each village was the village Chief. It is he who organized the villagers' contribution for the work activities agreed on with the Électriciens sans frontières teams.

4. PROBLEMS ENCOUNTERED

Very quickly during the project's first year, the Chinese pico hydro turbines experienced operating failures. The poor quality of the ball bearings, their premature wear or rapid corrosion limit the bearing life to a few weeks. If unreplaced, off-centering of the rotating part causes friction which may result in the separation of the permanent magnets and block the machine. Other manufacturing anomalies were observed and the manufacturer provided no help. Given the widespread availability of this type of equipment in northern Laos and its low cost, it was decided to improve the reliability of the pico hydro turbines before use. This operation consisted in equipping the machine with quality waterproof bearings, rewinding the stator with copper, balancing the rotating part and redoing all seals. This significantly improved the pico hydro turbines' operating reliability.

36 VILLAGES
electrified between 2007 and 2012

18
field missions

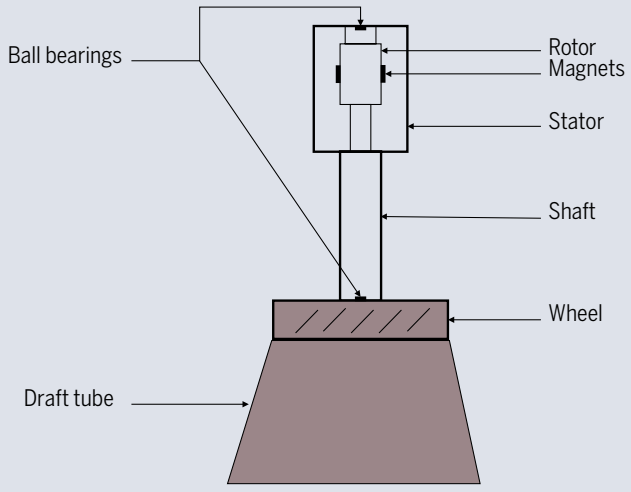
1,000 W
per 10 families

At the same time, Hydrotech pico hydro turbines manufactured in Vietnam were tested. They had the reputation of being the best products available on the Asian market. Despite the prior expert assessment of Hydrotech pico hydro turbines, which showed them to be correct before being procured, when they were put in service they quickly experienced repeated failures which made it necessary to drop this solution because they endangered the project on several counts: discouraging of population vis-à-vis maintenance, and a poor service quality which could encourage the beneficiaries not to pay the access to electricity fee.

These technical hazards, as well as the cost constraints, confirmed the need for the villagers to learn how to improve the reliability of the Chinese pico hydro turbines. Thus 30 Chinese pico hydro turbines, purchased from a local supplier at Phôngsaly, were made reliable during the training course on «maintenance for improved reliability of pico hydro turbines». This solution turned out to be the right one, because the technicians subsequently demonstrated that they master the process and have fully taken it on board.

Other constraints could also complicate the use of pico hydro turbines, such as variations in climate and the strong flooding caused by the monsoons. In anticipation of the risk of equipment damage, the facilities were designed so as to allow dismantling of the turbines in case of very high water.

Diagram of a pico hydro turbine and its components



Source: Électriciens sans frontières

Figure 2

Finally, in the matter of the transfer of skills, the selection of young people was the responsibility of the authorities, district Chief, village Chief, Ministry of Energy and Mines. But the observed low degree of instruction (linked to child work and the obstacle of different dialects) has considerably complicated the training courses and has required a lot of adaptation, including as regards the material used and its contents. The theoretical training part required the most in-depth change, undertaking first a practical approach followed by theory periods, and also limiting training to the essentials on the acquisition of basic knowledge.

5. IMPACTS OF THE PROJECT

On a societal plane, the project impacts were multiple.

In 2011, a study was conducted in 6 villages on the basis of interviews and site inspections, in order to make a mid-course review of the project. Of the 6 villages, only 5 were fully able to answer the questions of the investigators, since in the sixth village, the insufficient water flow in the turbine at the time had not allowed full use of the facilities.

The study covered the following areas:
- Analysis of the electrical consumption of the villagers
- Satisfaction of beneficiaries and impact on their daily lives
- Analysis of the running of the village committees
- Savings for the villagers
- Compliance with the rules for the use of electricity and the facilities
- Application of the maintenance protocol
- Verification of the condition of the facilities and equipment reliability
- Analysis of the operating procedures in the villages

Of the 177 families interviewed, the reported satisfaction rate was 100%.

In 3 of the 5 villages, all of the families were connected to the grid.

The villagers use first electricity to get light. On average they use the lights for 4 hours in the evening (from 6 p.m. to 10 p.m.) and 2 hours in the morning (5 a.m. to 7 a.m.). Families have between 1 and 3 light bulbs according to their standard of living. After that, almost all of the electrical devices in the villages with battery chargers are music devices. According to the villages Chiefs, half were purchased after the arrival of collective electricity.

Table 1. Results of the mid-course project evaluation

Village	Number of turbines	Installed power	Number of families connected to the grid	Number of devices	Percentage of families equipped	Connection rate	Collection rate
Hat Phay	1	1,000W	20	5	25%	100%	100%
Hat Ko	2	2,000W	45	13	29%	100%	100%
Phon Hom	3	3,100W	48	25	52%	100%	95%
Poussoumnea	2	2,000W	31	28	90%	68%	100%
Vanea	1	500W	33	16	48%	48%	100%

Source: Électriciens sans frontières

There are also a few fixed phones (1 or 2) per village.

During this survey, the main changes reported during the interviews were: the ease for performing some household tasks (meals), the improvement in working conditions in the evening for both men and women (repairing of fishing nets or farming instruments for men, sewing and repairing clothing for women), the improvement of social life (school work for children, listening to music CDs in a number of cases) and care conditions for the doctors who visit the families.

The impact of the program has been less in terms of the development of income-generating activities, because the electrification through low capacity hydroelectric production does not supply sufficient power. However, especially for the women who already carried out embroidery activities (local crafts), having quality lighting has allowed them to work in better conditions, even opening up a new field of activities for those wishing to do so.

A year after the project, computing the costs avoided and comparing with the expenditures generated by the arrival of electricity (fee) shows that families could save between 2 and 5 per cent of their annual income according to circumstance. The average cost of the previous energy system was LAK 25-30,000 per month on average for a family, against a monthly LAK 2,000 fee with the new system. The cost has therefore been divided by 10.

"A YEAR AFTER THE PROJECT, COMPUTING THE COSTS AVOIDED AND COMPARING WITH THE EXPENDITURES GENERATED BY THE ARRIVAL OF ELECTRICITY (FEE) SHOW THAT FAMILIES COULD SAVE BETWEEN 2 AND 5 PER CENT OF THEIR ANNUAL INCOME ACCORDING TO CIRCUMSTANCE."

Table 2 summarizes the savings in kips per family over 10 months in the villages. It must be remembered that these savings do not take into account the exceptional collections, which are hard to quantify.

Table 2. Savings per family over 10 months (in kips)

	Hat Phay	Hat Ko	Phon Hom	Poussoumnea	Vanea	Total average
Family 1	210,000	107,000	544,000	550,000	42,000	
Family 2	184,000	182,000	436,000	512,000	382,000	
Family 3	954,000	330,000	306,000	962,000	181,000	
Family 4	416,000	215,000	64,000			
Family 5			-31,000			
Average	**441,000**	**208,500**	**263,800**	**674,700**	**201,700**	**357,500**

Source: Électriciens sans frontières

The new system is more expensive than the previous one only for a very poor family. This family used almost no oil and has had to change its light bulbs several times.

In a few cases, it was also found that access to electricity was accompanied by work to improve the home, which could extend to a permanent construction. This phenomenon remains marginal (3 to 4 houses in a village of 50 families), but reflects the emergence of a new and encouraging movement. During the various site inspections, and particularly during the survey conducted at the end of one year in the 6 villages, no problems of breakdown or malfunction of the distribution network and of the internal installations were observed. This means, in particular, that the maintenance of the network surroundings is satisfactory. As regards internal installations, a few connections made by the households themselves have been observed, but they remain marginal and have not altered the safety conditions of the facilities nor apparently caused any incidents. The danger actually remains limited insofar as the connection facilities (units, wiring, etc.) have been placed high enough to put them out of reach of young children.

From a technical viewpoint, it would appear that the technicians are capable of replicating what they have learned, and that the necessary parts for basic maintenance are easily accessible and stocked. In each village, trained technicians quickly put into practice their skills since the facilities require a daily maintenance, a monthly lubrication for pico hydro turbines equipped with greasing nipples, and bearing replacement and lubrication every 2 to 6 months. In practice, the various inspections carried out showed that beyond the differences observed between villages, the larger pico hydro turbines were very well maintained, while the less powerful turbines supplying fewer homes were not always well maintained. The size of the sample considered for this project, however, makes it impossible to draw general conclusions on this point.

In all the villages visited during the various missions, or during the survey carried out after one year, it was found that the management model put in place allowed the financial and organizational sustainability of the operation in the medium term.

A village was able to install an additional pico hydro turbine, together with a distribution network, and to supply new families thanks to the savings achieved. These installations carried out by the villagers themselves under the supervision of the technicians, were operational during subsequent visits. It is the only example observed to date of replication of a collective installation. In another village, the villagers replaced a turbine that had a serious breakdown. In all cases, the modification of the Chinese turbines had been carried out satisfactorily. The technicians thus demonstrated their ability to set up new installations.

The only brake to explain the limits of the replication of facilities lies in the cost of the fee. This had been set rather low, taking into account the low incomes of some families, and it appears that it results in a collection rate that is very encouraging for the project's sustainability, but it does not allow investment in new installations (excepting the exceptional effort of the inhabitants of one village).

Several villages have thus had to conduct "exceptional collections" of a further LAK 2,000 to 10,000 per month. The management committees therefore considered raising the rates at the end of a year, but preferred to stay on current pricing levels. Thus, the savings are reflected more in an improvement in the financial situation of the households that by a significant deployment of new turbines (see Figure 3).

Figure 3 and Table 3 were made from the impact assessment carried out in 2015 by the Commission Climat Développement de Coordination Sud of 6 access to energy projects[3], including the Laos project of Électriciens sans frontières. Figure 3 serves to measure project efficiency by quantifying the main benefits of the project broken down to one unit of investment made on the one hand by the lender, and on the other hand by the users (the unit being USD 10). In the case of the Phôngsaly province project, the profits in question are the savings of the households and the economic gain for the sector's stakeholders (the technicians trained to maintain the installations):

3 http://www.coordinationsud.org/wp-content/uploads/2015_EtudeCCD_Acc--s----l--nergie_FR.pdf

Project efficiency

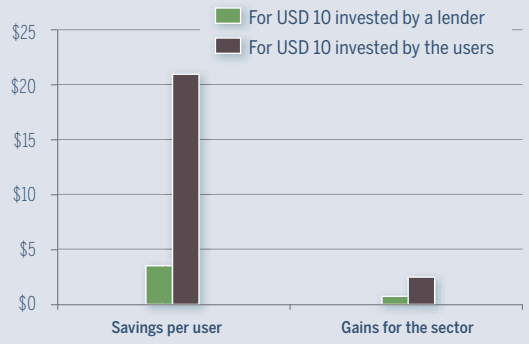


Figure 3

The main lesson drawn from this graph is that the impact of the project is clearly in favor of the direct users (households).

By contrast, the benefits for the economic stakeholders, the technicians, are much lower, as evidenced by the result of the economic impact study below. The study aims to emphasize the long-term impact of the project as a whole taking into account three criteria: the savings made through the project (substitution of energy sources), the savings made by the sector, and the jobs generated by the activities related to the monitoring and maintenance of the technology. The study of the savings was based on internal data, after analysis of savings on the purchase of fuel, and on the basis of a survey of 20 households in 4 villages. The evaluation of jobs created corresponds to the analysis done by the project team and shared with local stakeholders, of the hourly charge for maintenance over a year (a full-time job for a year corresponds to 1,600 hours/year).

Table 3. Results of the economic impact study

	USD saved	USD earned in the sector	Full-time jobs created in the sector
Construction		29,187	9.225
Year 1	58,438	1,235.43	0.97619
Year 2	55,655	1,176.60	0.929705
Year 3	53,005	1,120.57	0.885434
Year 4	40,385	853.77	0.674616
Year 5	33,654	711.47	0.56218
Year 6	32,051	677.59	0.53541
Year 7	30,525	645.33	0.509914
Year 8	29,072	614.60	0.485632
Year 9	27,687	585.33	0.462507
Year 10	26,369	557.46	0.440483

The low level of the single fee makes it impossible to set aside significant revenues for the sustainable development of an activity beyond mere maintenance (for instance, installing new turbines). This led to a revision of pricing levels for the continuation of the program, with several rates.

It was also noted that efficiency is higher from the user's viewpoint than from the lender's, which is typical of an electricity access project with a significant initial investment in capital.

CONCLUSION

The aim of the project in Nhot Ou and Phôngsaly districts between 2007 and 2012 was to give poor populations in 36 very isolated villages access to a minimum of electricity using of pico hydro power production means.

The skills transfer has enabled a standalone but partial deployment of the mini hydro power for the populations, safely. At the end of the project, the trained technicians proved in two villages that they were capable of replicating or replacing the installations, which was essential to the project.

Several avenue of progress have been identified and taken into account in the continuation program initiated in 2014 with a view to electrifying a dozen other villages in Phôngsaly province by 2017:

- *the sustainability of hydraulic works and the associated construction quality,*
  ***Proposed solution:** in the continuation of the project, the presence of a local hydraulic structures engineering consultant made it possible to work further on this issue and improve the robustness of the works, thus reducing the burden of maintenance.*
- *institutionalization of the management committees and the still partial involvement of women.*
  ***Proposed solution:** these issues continue to be worked on with the support of local consultants in social engineering with good knowledge of the north Laos region.*
- *the absence of watercourses or sufficient flow in some villages,*
  ***Proposed solution:** the current project provides for different hydro power or photovoltaic solutions for the electricity production according to the locally available resources.*
- *a single pricing rate linked to the lowest incomes, is sufficient to maintain the facilities but insufficient to allow for their replication,*
  ***Proposed solution:** a multi-level pricing grid matching the household incomes makes it possible to generate sufficient revenue to consider a wider deployment of the program.*

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