Lao
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Pico-hydropower

Technography of pico-hydropower in the Lao PDR

Report

003

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Vientiane

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Lao Institute for Renewable Energy

LIRE

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About

About LIRE

LIRE is a non-profit organisation dedicated to the sustainable development of a self sufficient renewable energy sector in the Lao PDR. The institute offers agronomical, technological and socio-economic research services, and works to provide a free public resource of information and advice on the use of renewable energy technologies in Laos. LIRE strives to support the development of the country by exploring commercially viable means to establish renewable energy technologies in rural parts of the country, in areas without connection to the national grid and with little access to technical expertise.

About the report

This report is based on the MSc thesis of Mattijs Smits from August 2008.

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Introduction

This report aims to provide a detailed description of pico-hydropower in three target areas in Laos using a technographic approach. In so doing, it will be the first detailed description of this widely used technology in Laos, including the socio-technical networks around it. This technology gained ground in a context where grid electricity is not available in many remote rural areas of Laos. Centrally planned off-grid electrification technologies, such as micro-hydro and solar home systems, have failed to provide a substantial number of people with electricity. Therefore, people have started using alternative ways to generate electricity that are available at the market and can be installed without much technical knowledge. Pico-hydropower is one of these systems, but has so far received little attention from researchers and policymakers, although its functions have greatly benefited many people in rural areas.

The set-up of this report leads the reader through the many relevant aspects of pico-hydropower in Laos by means of four distinct, interrelated sections. The chapter starts with the introduction of the low-head propeller pico-hydro unit, which is by far the most used type. Then, the amount of units and the distribution channels, leading from China and Vietnam to small village shops, are mapped out. The properties and the market distribution lead into the description of the use and functions of pico-hydropower electricity. This section shows the variety of geographical factors and the ability of people to creatively adapt to these circumstances. The last section, a financial analysis, compares pico-hydropower in Laos to other technologies, which shows that low-cost pico-hydro units provide the cheapest off-grid electricity. The last part integrates the actor-networks identified.

1. Pico-hydropower hardware

The first part of this technographical description deals with the hardware of pico-hydropower: the types available, the vulnerable parts and the electricity generated. Hereby, this section covers the technology in a classical or technological determinist sense. However, it is necessary to have a notion of the functioning of the units, before being able to understand how these characteristics influence the network around the use and market distribution of pico-hydropower in Laos that follow.

Different types of pico-hydro

The type of pico-hydropower unit influences the way it is used, the civil works needed and the range of power that can be generated. There are a few different types of pico-hydropower technology found throughout the world, which all have their own characteristics. The most prevalent type of unit in Laos is the low-head propeller type (Figure 1). This type of pico-hydro unit is called low-head, because the unit requires only a small drop of water to function properly, provided that the flow, i.e. the strength of the current, is sufficient. The water falls into the propeller or turbine at the bottom of the unit, thereby making the shaft turn. In the upper part of the unit, AC-electricity is generated by an alternator. The rated capacity of the unit varies from 200 Watts up to several kilowatts, but the unit producing less than 1 kW are the most popular in Laos.

Figure 1 - Low-head propeller pico-hydro units

Figure 2 - 'Turgo' pico-hydro unit

Besides the low-head propeller unit there are several other types of pico-hydropower units. First, there are the so-called ‘turgo’ hydropower units, which require more head and have to be connected to a penstock, long pipe to channel the water, to function. These units can generate power ranging from 500 W upwards. Because they need more head they are better suited for hilly and mountainous areas. The installation is also more complicated, because of the construction of the penstock (long pipe to channel the water). Although they are far less popular than the propeller units, they can be found in Laos. Types of pico-hydro not commonly seen in Laos are high-head 'pelton wheels' or 'peltric sets' and medium-head 'cross-flow turbines'. These types are reported mostly in Nepal and Philippines (ESMAP, 2005).

The type of pico-hydro unit that is most appropriate is influenced by the terrain and by the ease of installation. In Laos, the low-head propeller type pico-hydro unit is most common, because the average amount of head is not very high. Moreover, the installation is done manually, without instructions and sometimes without construction material available, which also favors the easy-to-use low-head pico-hydro unit. This type of technology is meant whenever pico-hydro is mentioned in this report, unless mentioned otherwise. Still, also within the category low-head propeller units, there are differences, e.g. the power output and the quality. These differences can often only be seen from the inside of the units and the moving, and therefore vulnerable, parts.

Vulnerable parts of the low-head pico-hydropower turbine

The low-head propeller pico-hydropower unit that is most common in Laos has three essential parts that are vulnerable to damaged or wear. Because the units are working 12 to 24 hours, these parts have to be replaced sometimes, which can considerable add to the costs. Figure 3 shows a schematic picture of a low-head propeller pico-hydropower turbine and the different parts. The three parts that have to be replaced regularly, for certain models of low-head pico-hydro units, will be discussed below.

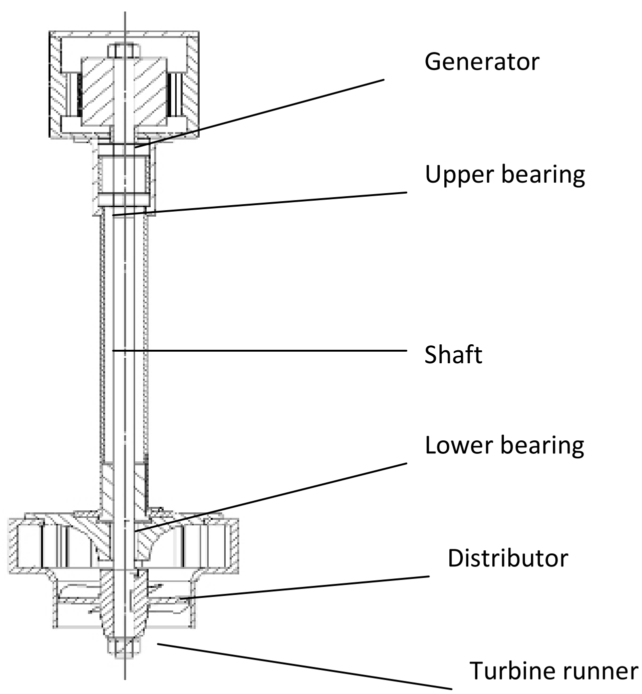


Figure 3 - Schematic picture of low-head propeller type pico-hydropower unit (Entec, 2000)

First, the upper part, or the alternator, is the place where the actual electricity is generated. Usually, there are three coils inside with copper windings. The magnetized metal inside turns so that inductive electricity is produced. There are two possible types of failures of this part: the metal part can become demagnetized, or, more common, the copper windings can wear or burn out. In the latter case, one or more windings has to be replaced. Second, pico-hydro unit has two bearings, one in the top and one in the bottom of the unit, that facilitate the spinning of the shaft. Both of these can wear out after a certain period of time, depending on usage and quality of the bearings, but they can be replaced. Finally, the turbine or the propeller itself is vulnerable, especially when the water runs through it unprotected. Branches, garbage or fish can get stuck in the turbine and damage it. This can also have an adverse effect on the generator and on the appliances installed, because the blocking of the turbine causes a sudden drop in voltage. The use and costs of pico-hydro in Laos cannot be understood without taking the sometimes failing parts of the unit into account. The quality and possibly damaged parts also negatively influence the output of electricity.

Electricity output

The electricity output of the pico-hydro units can sometimes fluctuate, which can cause damage to appliances and lights connected. The electricity generated by pico-hydropower is not stored and usually not regulated. This means that all the electricity has to be used directly and that the performance and the quality of electrical output of the unit is directly dependent on the flow and head of the water, the type and state of the pico-hydropower unit and the appliances connected. The flow and the head of the water determine how fast the shaft spins and how much power is generated. The theoretical maximum potential power of a river or stream can be calculated by using the following formula:

$$Flow(l/s) \times Head(m) \times Gravity(m/s^2) \equiv Power(W) \quad (1)$$

This formula indicates that the power (W) depends on the strength of the current (or flow) and the height of the drop of water (or head). These two factors are multiplied by the gravity to determine the power. Thus, a certain position in a river or stream gives a certain theoretical maximum power output. An example of the effect of variation in flow and head for a pico-hydro turbine can be seen in Figure 4. The type of unit and state of maintenance determine how much of this potential can be transformed into electricity. Typically, low-head propeller pico-hydropower have a low efficiency, around 30%, compared to other hydropower technologies. It depends on the manufacturer and the state of maintenance (especially the bearings tend to wear out very quickly) how much the actual power output is.

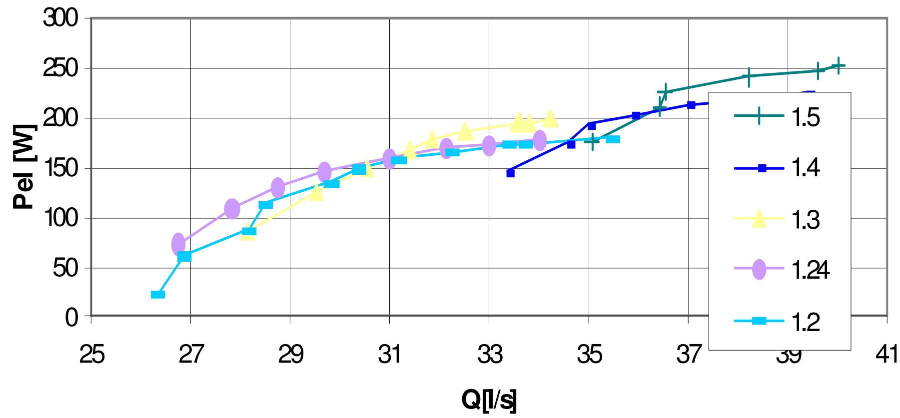


Figure 4 - Power output (P_{el}) variation for a low-head propeller pico-hydropower turbine with varying flow (Q) and a different constant heads (colored lines) (Entec, 2000)

It is not only the power output determines the performance or quality of the electricity, but the voltage level and fluctuations as well. If the voltage is too high or too low, this can lead to damage to appliances that are connected. The voltage can be determined by Ohm's law:

$$Voltage(V) = Current(I) x \operatorname{Re} sis \tan ce(R) \quad (2)$$

This formula shows how the voltage is determined by the current and the resistance. Simply put, if the resistance changes, e.g. fewer or additional appliances, this leads to a change in voltage level. This is the same effect as when one connects high powered electrical appliances and the lights dim for a second in a situation with grid electrification. However, because the total power is much less for pico-hydropower and a small drop has more impact, this effect is more problematic. The voltage level can also change as a function of the distance of the pico-hydropower unit from the applications. This can also be derived from the previous formula as well. Cables have a certain resistance, depending on the length of the cable, its diameter and the quality. The longer, thinner or poorer quality the cable, the higher the voltage loss.

Voltage problems can be overcome by connecting a volt regulator to the pico-hydropower unit. This is a device that adjusts the voltage to a certain level in order to prevent damage to electronic devices when the voltage level becomes too high or too low. Some pico-hydro units have integrated voltage regulators, but these are more expensive than the ones without. In Laos, the overwhelming majority of the pico-hydropower units installed do not have integrated or external voltage regulators.

Conclusions about hardware

The description of the hardware of pico-hydropower units provides the basis for the understanding of the pico-hydropower technology in Laos. First, the overwhelming majority of low-head pico-hydro type of unit can be related to the geography of the country and the independence of the people when installing the unit. Moreover, the electricity output and the voltage fluctuations have a strong impact on the potential damage to light bulbs and devices connected. This and the replacement of vulnerable parts, bearings, windings and propeller, all add to the total lifetime costs of the system. However, this has also created a network of traders and shops around pico-hydropower in Laos whom are involved in trading and selling units and spare parts.

2. Markets and distribution of pico-hydropower units

This section of the technography describes the number of units in Laos and the network of shops, traders and merchants around it. By doing so, it extends the description of the technology outside the realm of technical details only into the networks of the market. This is necessary to understand how pico-hydropower has been able to spread to many place, even in the remote areas of Laos, what kinds of people are involved and what kinds of channels are being used. In addition, it also shows why the price and quality of pico-hydropower units is currently very low. This adds another layer of information about the under described phenomenon of pico-hydropower in Laos.

Number of pico-hydropower units in Laos

Although it is difficult to make an accurate estimation, there is evidence that there are ten thousands of pico-hydropower units in Laos, making it easily the most used renewable energy technology in off-grid areas. The lack of information available makes it hard to come up with reliable numbers though. The government does not keep track of the number of units installed in the country, given the empty column of 'pico-hydro' in their National Electricity Statistics (MeM, 2005). An associate Professor on Renewable Energy Technology of the National University of Laos estimates that there are over 100,000 pico-hydropower systems in the north of the country only. He bases this on his experience, and some small research activity on pico-hydropower (interview 13). The only quantitative source of information comes from a training that has been carried out by the Village Off-Grid Promotion and Support Enterprise (VOPS). The training was carried out in a selected number of districts and villages in five northern provinces of Laos, where people use a lot of pico-hydro. In 337 villages in 20 districts, a total of 7051 working pico-hydro units were found, providing electricity to 10.683 households. From these numbers, it can be derived that 27% of the households have a pico-hydro unit, providing electricity for 41% of the people in these villages. In general, the northern provinces of Laos are more suitable for the use of pico-hydro, because it is more mountainous than the middle or the south. Fieldwork in Bolikamxay in this report, however, shows that the units are not only used in the north. In addition, there is evidence about use of pico-hydropower in the south as well (e.g. Baird, forthcoming).

An estimation of the number of pico-hydro units and electrified household has been made for this report as well. The VOPS data has been taken as a starting point, but used in a conservative way. It is assumed that in the off-grid villages in mountainous provinces 20% of the households own a unit that provide 30% of the households with electricity and 4% and 6% respectively in the other provinces.[1] This would mean that there are around 60.000 pico-hydropower units in Laos, providing 90.000 people with electricity. Because of the expansion of the national grid since 2005, the number might be lower. However, the numbers of pico-hydro units in the villages surveyed for this research are much higher than this, with over 60% of all households owning a unit. When you include people sharing their unit, the total electrification rate of some surveyed villages approaches 100%. These figures are probably so much higher, because the villages were specifically chosen for their high pico-

[1] The northern mountainous provinces are Phongsaly, Luang Namtha, Oudomxay, Bokeo, Luang Prabang, Huaphan, Xayabouly and Xieng Khouang. The village data come from MEM (2005).

hydro occurrence, whereas the VOPS survey probably also covered villages without many units per village.

There is some information available on the use of pico-hydro in Vietnam as well. This country, neighboring Laos, shares many characteristics (same type of terrain, similar ethnic groups) with Laos and can therefore provide useful comparative information. A report of Entec (2000) estimates a number of 120,000 pico-hydropower systems in the range of 100 to 500 Watt supplying 130,000 households in the whole of Vietnam. These estimations, however, are also based on limited and extrapolated sources of information. Similar numbers can be found in reports of ESMAP (2005) and DFID (2004), which estimate a range of 100,000-130,000 and 120,000 systems respectively. Given the lack of empirical data, the latter two publications might have based their estimations on the figures of the Entec report.

The development of low-head pico-hydropower units in Vietnam is said to have started in the course of the 1980s (Entec 2000; ESMAP 2005). Field work data on shops for this report indicates that the development started somewhat later in Laos. Shopkeepers indicate that in the course of the 1990s the sales picked up and reached its height around 2000. After 2000, the sales stabilized or went down, especially because of the grid extension program in certain areas.

Shops

Pico-hydropower units can be bought from shops in almost every place with a small market. Shops selling pico-hydropower units are usually those selling all kinds of tools, equipment, machines and hardware. Like most shops in Laos, they are typically to be found at or around markets. These markets commonly consist of permanent stands or small stores that are closed at night. In the larger centers, markets are sometimes specialized in single types of goods, but in smaller towns all products are sold at the same market. Similar kinds of shops are usually located in close proximity to each other. Generally, the shops are small in size and ran as a family business. All products are on display and fixed prices are rare. Shops in Laos are mainly owned by Laotians, but sometimes by Chinese, Vietnamese or Thai people as well. Most interviewed shopkeepers were of Lao nationality, although especially in Phongsali there were some Vietnamese people running shops, because of the proximity to the Vietnamese border.

Figure 5 - Typical shop selling pico-hydro units, Lak Xao, Bolikamxay province

There are many shops in Laos where one can buy low-head propeller pico-hydropower units in the range of 300 W to 1 kW. The number of places generally depends on the size of the town or city, but even more on the demand in the region. A good example is the biggest city and capital of Laos, Vientiane. In this city there are only a few shops selling pico-hydro, because the surrounding area is almost completely electrified by the national grid. The areas that are included in this research have demand for pico-hydropower and can therefore be classified by size ( ).

Table 1 - Overview of shopkeepers interviewed

Province	*Place*	*Type of place*	*Number of shops*	*Number of shops interviewed*
Bolikamxay	Lak Xao	District capital	3	3
Xieng Khouang	Phonesavan	Provincial capital	8-10	6
	Chomthong	District capital	2	2
Phongsali	Mai	District capital	3	2
	Kuah	District capital	4	2

In the provincial capital of Xieng Khouang, Phonsavan, there is a lot of choice in terms of pico-hydropower. Pico-hydro can be found at the Nam Ngam market and at the *thalat mai* (new market) near the city center. The former market has only two shops selling pico-hydro, but the latter has no less than eight of them. The number of units being sold varies between a few and more than 80 units per month. Because the shops sell approximately the same range of models, one seller mentioned that the place in the market could might explain this difference (interview 33). In addition to these shops at the market, one big shop outside the market areas was found, selling over 200 low-head propeller pico-hydro units per month. Besides these conventional types of pico-hydro, the shops also sold other types: propeller types with higher power output (up to 3 kW) and 'turgo' pico-hydro turbines, some from China and some from Vietnam.

Figure 6 - Three shops in a row selling pico-hydro units at 'thalat mai', Phonsavan, Xieng Khouang province

In each of the four district capitals included in this research, Lak Xao (Bolikamxay), Chomthong (Xieng Khouang) and Mai and Kuah (Phongsali), there were between two and four shops selling pico-hydro. The proximity of Lak Xao and Mai to the Vietnamese border seemed to have little or no effect on the number of shops and the price of pico-hydro. The district towns are not the smallest centers where pico-hydropower units can be found. Many small shops in small towns or even villages in rural areas have at least a number of units for sale. These shops tend to have fewer options and sometimes sell only the most popular type of pico-hydro (the 500 watt low-head pico-hydropower propeller unit). Thus, pico-hydropower units can be bought in most rural areas where there is no grid electricity and even in remote areas in poor districts, e.g. Viengthong, Mai and Kuah district. These shops almost completely depend on traders for their supplies.

Traders

Chinese and Vietnamese traders are key actors in the distribution system of pico-hydro units in Laos, because they supply shops and markets, but also people directly. All but one of the shopkeepers interviewed for this research obtained their products from these traders, whom are of either Vietnamese or Chinese nationality; none of them were from Laos. As mentioned before, shops selling pico-hydropower turbines commonly sell all kinds of equipment, tools and machines. Different traders come by to sell different kinds of products, including pico-hydro units. Most shops have fixed traders for fixed product categories, such as pico-hydropower units. The payments to these traders is always in cash, but some traders allow shops to pay later or in terms as well. Traders commonly pass by at periods ranging from every few days up to a month, depending on the volume of sales and the size of the shop. In addition, some shopkeeper have the phone number for their traders, so they can order in advance or place additional orders if necessary. Only one shopkeeper interviewed, of Chinese nationality, actually drives across the border to get his products there.

The shops selling pico-hydro are not always the last stop before they reach the end-user. About half the interviewed shopkeepers indicate that they also sell to other merchants sometimes. These merchants in turn go to villages in remote areas to sell the units to the end-users. This is attractive for people in remote areas, because it saves them time and money to go and buy the units themselves. Thus, there is a fine network of traders supplying shops, but also supplying individual customers, based on supply and demand. No advertisement was observed, indicating that word of mouth is the most important source of information for pico-hydro customers. The people interviewed often said they chose a certain shop or trader on the advice of friends or family. This is also a way to limit the risk of bad quality systems.

The origin and quality of pico-hydro units according to shopkeepers

Discussions about the origin and quality of pico-hydropower units with shopkeepers shows the limited knowledge and influence they have on the products they sell. Instead, Chinese and Vietnamese traders determine the kinds of pico-hydropower units that are being sold in Laos. The limited and opaque information that is available about the origin and quality of the units confuses the shopowners and favors the position of these traders even more.

The shopkeepers are by no means found to be experts on pico-hydropower and usually don't know where their products come from. None of the interviewed shopkeepers knew where, in which city or factory, their pico-hydro units were produced and sometimes even the country of origin seemed unclear. There are three different factors that can explain this. First, some shopkeepers think the nationality of the traders indicates the origin of their products, for example, that Vietnamese traders only sell Vietnamese products. A shopkeeper at the market of Phonesavan stated this directly: " I only trade with Vietnamese people, so I only have Vietnamese products" (interview 30). Other shopkeepers, however, seem to be aware that this does not necessarily have to be the case, because another shopkeeper at the same market said: "the producers are Chinese, but they often come through Vietnam" (interview 28). Thus, the shop owners are not always a where of the country of origin of their products, because the relate this to the nationality of their traders.

Secondly, there is uncertainty over different types and colors of pico-hydro units and their relation to the country where they are produced. There are different types of low-head pico-hydropower turbines that look more or less the same, but are in different colors, usually green or metallic. Some shopkeepers seem to think that the color explains the difference in origin: "If you go to the border of China, you can buy the green picos" (interview 29). However, a fellow shopkeeper a few meters away says that "the green color does not mean anything. You can just order any color you want" (interview 30). Again, two completely contrasting opinions from shop owners who are only a few meters away from each other.

Figure 7 - Different types of low-head pico-hydro units at market Phonsavanh, Xieng Khouang

Figure 8 - Chinese characters on Vietnamese pico-hydro unit, market Phonsavanh, Xieng Khouang

Finally, the labels and absence of instructions and labels also causes confusion among the shopkeepers on the country of origin of the pico-hydro units. None of the interviewed shops supplied instructions and many units do not have labels. But, even if they have them, this information might not reveal the true origin of the unit. Most of the pico-hydropower units with labels contain Chinese characters, but several interviewed shopkeepers indicated that they still originate from Vietnam: “In the Vietnamese factory, they put the Chinese labels” (interview 29), “Even if there is a Chinese sticker on them, the products are still Vietnamese!” (interview 32). This type of copying and relabeling is common in Asia, as mentioned by a project coordinator of VOPS: “Copyright doesn’t really exist in Asia” (interview 25). This makes it difficult for shopkeepers to know where their products really come from.

Thus, there are several factors that cause confusion and contradictory opinions about the way to trace the origin of pico-hydro units in Laos. Some of the quotes show that certain shopkeepers are well aware of the problem of tracing the origin of their products and use it to their advantage[2]. The owner of the big shop in Phonesavan explains that the preference of people is very important: “Some people like Chinese products, some like Vietnamese. That’s why I sell both” (Interview 27). Not many shops claim to sell both types of units though. In the district capital of Kham district, Chomtoong, there are two shops selling pico-hydropower units. One of them is owned by a Chinese family and sells Chinese products, including pico-hydropower units. The other shop is owned by a Laotian family and sells Vietnamese ones.

[2] A seemingly reliable tip from one of the shopkeepers to know where the pico-hydro unit comes from is to look at the number of wires coming from the unit: Vietnamese units have four, whereas Chinese ones only have two.

Discussions about the quality of the Chinese versus the Vietnamese pico-hydropower units also provides mixed answers. Some shopkeepers claim that the quality of Chinese pico-hydro units is better than the Vietnamese ones, while others claim the opposite or say that there are no differences. This might have to with the confusion about the origin, since some shopkeepers might be under the impression that their products originate somewhere else. Another factor is that not all shops are selling the same type of products. Although differences cannot be observed by looking at the labels, careful observation shows that not all products look the same, probably indicating a difference in quality as well. Lastly, the shopkeepers are probably claiming that the products they sell are better than the ones they are not selling, thereby biasing the discussion. Even a project manager of VOPS with pico-hydro experience could not tell which pico-hydro systems were better (Interview 25).

Turning again to pico-hydro research in Vietnam gives some further perspective on where the pico-hydropower units in Laos probably come from. The ESMAP (2005) report states: "Pico-hydro systems in Vietnam are imported mostly from China, illegally, where they are manufactured near Nanning City." Entec (2000) also mentions that "Chinese low-cost MHU [micro-hydro unit, same as pico-hydro unit, MS] are manufactured at a small family-business workshop in the city of Binh Lac, north of Nanning City" where "[t]he workshop produces about 1000 units of pico hydro within a month (output 180W, rated 300) with 30 workers". Nanning city is a place in Southern China about 150 km northeast from the Vietnamese border and 300 km from Hanoi. According to the report of Entec, the pico-hydropower units are bought by traders from China, Vietnam, Cambodia and Myanmar. In Hanoi, there is supposed to be a big trader who redistributes low-cost pico-hydro units via a complex network of smaller traders over Vietnam and probably Laos as well.

The same Entec report also mentions that "the Chinese low-cost units dominate the market with over 90% coverage." and that "[a] small number of Vietnamese private workshops had copied the Chinese MHUs and sold them through the same outlets as the Chinese originals. The units did not have a name plate or a brand name. The quality was said to be even lower than that of the Chinese low-cost units.". Unfortunately, the information from the Entec report is outdated and seems to be the only document of its kind. Moreover, it only talks about Vietnam and not about Laos. Still, it confirms, for example, that there are low-cost pico-hydropower units from both China and Vietnam. Furthermore, it also states that the quality of both Chinese and Vietnamese products is very low and that some of them do not have labels. The project manager of VOPS estimates that 60% of the low-head propeller pico-hydropower units come from China and 40% from Vietnam. (Interview 25).

The extensive discussion around the origin and quality of pico-hydropower units shows the strong integration of the Lao economy in the region and the influence of low-cost products from China and Vietnam in particular. The limited information from the shop owners and sources on pico-hydro in Vietnam shows that producers in China started manufacturing low-cost pico-hydro units and that manufacturers in Vietnam followed in a later stage. There are no indications any units are produced domestically. Some Vietnamese producers use Chinese labels in the hope to suggest the products are of better quality. In general, the lack of information and labels demonstrates the lack of importance of quality standards and the focus on cheap mass production. Because of the confusion about the origin and the quality, shopkeepers hardly play any other role but passing on products from the traders to the end-users. Therefore, especially the smaller shops, have limited, if any, influence on the quality. The traders, instead, play a more important role in deciding which kinds of products end up where, although they might also get their products from bigger traders as well. No traders were interviewed in this research, because of difficulties in tracking them down and the language barrier.

Conclusions about market networks

The analysis of the distribution and sales of pico-hydro in Laos puts the technology into national and even international perspective. An estimated 60.000 pico-hydropower units can be found even in the remotest areas of Laos, supplying a projected 90.000 households of electricity and is thereby the most important renewable energy source in off-grid areas. This large number of units are spread all over the country by a fine network of traders that extends into China and Vietnam where all the production takes place. Interviews and observations at shops show that it difficult to discern between different types of pico-hydro units and to assess their origin and quality. Therefore, these shop owners are not really in control of their products, but mainly pass on the units to other merchants or to the end-users. These market dynamics are important to understand how the technology fits in the local social and environmental reality of the users in Laos, which is the next topic of the technographic description.

3. Use of pico-hydropower technology

The description of the practices of the user to install, maintain and use their pico-hydro system and its function for peoples' livelihood will explain the widespread use of the technology in rural areas in Laos. The description of the installation of the system will show the strong link between social and natural factors of the systems and the flexibility of people to adapt to their local environment. Numerous small and inventive strategies are used to optimize the benefits using locally available knowledge and materials. The functions of electricity will be elaborated on and compared to show the benefits of pico-hydro *vis-à-vis* other available technologies in rural areas of Laos.

Purchasing a pico-hydro unit

Pico-hydropower units can be bought from shops or directly from traders and the choice is influenced by the availability of systems, willingness and ability to pay and references from friends and family members. As outlined in the previous section, people who want to buy a pico-hydropower unit have several options. They can either buy their unit at the provincial or district capital, or they can order or buy it directly from a merchant passing through their village. From the data collected for this research, the former way seems more common. The latter, however, was frequently mentioned in Mai district, Phongsali province.

When it comes to deciding which type of unit to buy, several factors play a role. First, it depends on what kinds of systems are available. In many smaller shops the choice is usually limited to one type of unit, Chinese or Vietnamese, and two or three different sizes: 300, 500 and 1000 Watts. Another factor is the electricity demand and the willingness and ability to pay accordingly. Naturally, 300 Watts systems are cheaper than those of 1000 Watts. The type of unit depends on the potential at the envisioned site of installation as well. A third and important factor is the experience of fellow villagers and family members. Many of the people interviewed indicate that references from others made them choose a particular kind of unit or shop. Observations that very often the same type of units are found in a certain village underlines this point. The price differences from the market surveys are not very big, so this factor is expected to play only a minor role in the selection process.

Types of installations

Pico-hydropower units in Laos are installed 'standing' or 'lying', but the actual installation can be anything in between and depends on the local geographical circumstances and the skill and creativity of people to adapt to these. Since the shops do not provide any instructions or manuals, people have to manage the installation of the pico-hydro unit on their own. However, as for the purchase, people in the villages depend a lot on the help and experience of others, notably family and friends. Most pico-hydropower units are installed by two or more people. On average, it takes about two days to install the system, including the construction of the civil works and the cables.

The time it takes to install depends on the type of construction used. Roughly, there are different two types of installation, with many variations in between. The difference is in the type of water resource and, related to that, the angle at which the pico-hydro unit is installed. The first type of installation is to have the pico-hydro unit in a small creek or river with the pico-hydro unit standing straight up (Figure 9 and Figure 10). This type of installation is suitable at places where there is enough head, but limited flow. Water has to be channeled to the pico-hydro unit through a canal and then drops on the turbine to make it spin. The water can be a diverted from a river or come from a small dam or weir made in locally available materials. This type of installation was frequently observed in the mountainous districts Kham, Mai and Kuah, where there are plenty of suitable small streams.

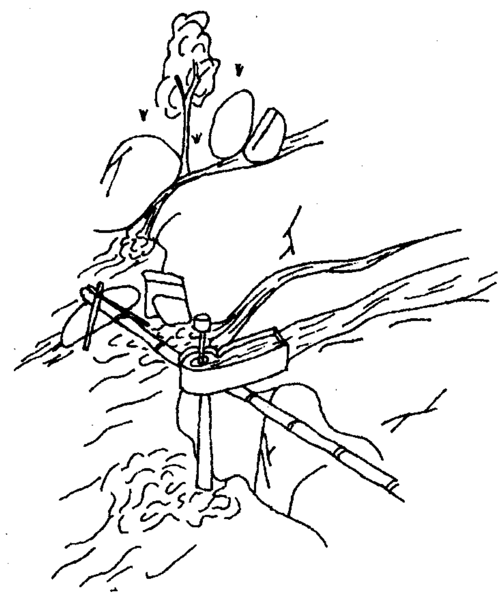


Figure 9 - Schematic figure 'standing' pico-hydro unit (Entec, 2000)

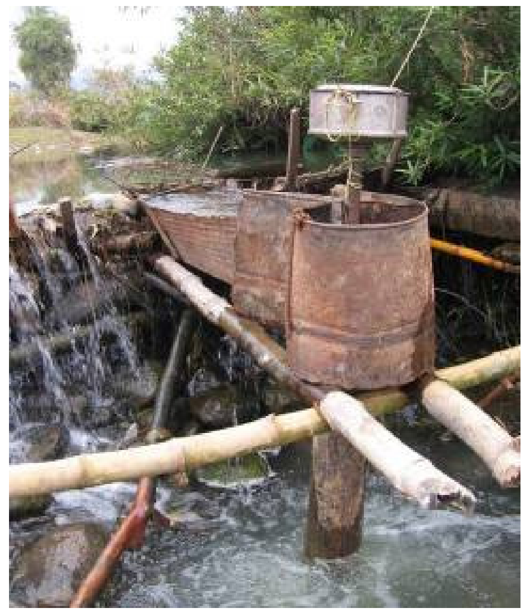


Figure 10 - Standing pico-hydro unit in Khaivieng village, Kham district, Xieng Khouang province

The other type of installation is used in bigger streams or rivers with the pico-hydro unit 'lying' down at certain angle. This type of installation is suitable for places where there is not much head, but a strong flow (Figure 11). The little bit of head which is needed comes from existing rapids or small dams, sometimes not more than a couple of boulders. The units are sometimes put in the middle of a river, so there is need for a strong construction to keep the unit in place. This is often done by making a tripod construction (Figure 12), with or without additional weir to create more flow at the place of the pico-hydro unit. Sometimes, also raft-like constructions are used (**Figure 13** and **Figure 14**). The tripod construction was the only construction used in Viengthong district, where there is a big river. It was also observed at some sites in Mai and Kuah district.

For both types of installations, people use simple solutions to protect their pico-hydro unit from being damaged. To protect the unit while it is in use, people install small nets or grids to 'filter' the water from branches, leaves and fish, which can potentially damage the unit. When the unit is not in use, the water inflow is sometimes regulated by blocking the flow. This is particularly easy at sites where water is diverted into a small canal, because this can be closed using a small floodgate. Other measures are simply to lift up the pico-hydro unit or to move it to the side.

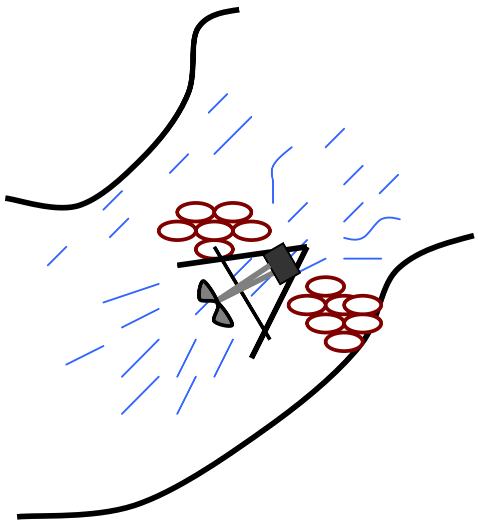


Figure 11 - Schematic figure 'lying' pico-hydro unit in River

Figure 12 - 'Lying' pico-hydropower unit in Nam Muan river, Bolikamxay

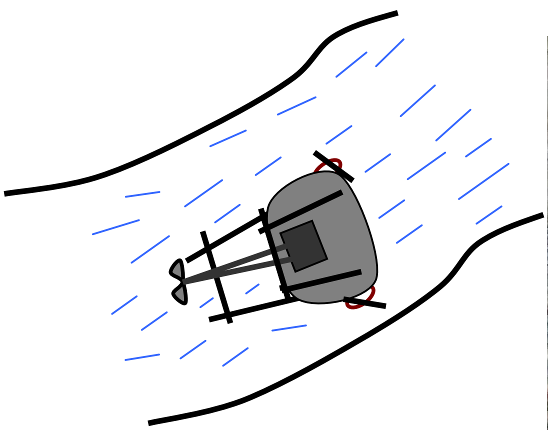


Figure 13 - Schematic figure pico-hydro on raft-like structure

Figure 14 - Pico-hydropower unit on a raft-like structure, near Sop Nhao, Mai district, Phongsali province

Another improvement often observed is to use an extension shaft for the propeller pico-hydro unit (see Figure 15). The longer shaft makes it easier to keep the alternator out of the water when it is installed at an steep angle. Therefore, this type of addition is mainly used for units 'lying' in bigger rivers. However, this improvement can also be observed in units installed in smaller streams (Figure 16). The use of boat propellers, normally used for speed boats, at the end of the turbine is often combined with the extended shaft. These can easily be installed at the end of the shaft to improve the performance of the extended pico-hydro unit.

Figure 15 - Pico-hydro unit with extended shaft at the Nam Muan river, Bolikamxay province

Figure 16 - 'Standing' pico-hydro unit in Sen Art village, Mai district, Phongsali province

The type of installation that people use is dependent on the type of water resources available at different villages. The specific place of installation in the village itself is an important decision as well, since the pico-hydro unit will not perform equally well in all places and it influences the amount of work during and after the installation. To begin with, the flow and the head of a site have a direct effect on the performance of the unit. However, people who install a pico-hydropower unit do not have the means and knowledge to obtain this information. They have to use their experience, copy others and rely upon trial error to select a suitable site. Shopkeepers and traders can play a role here as well by sharing their experience. In addition, people will try to limit the amount of civil works needed. In case of a standing pico-hydro site, this means looking for natural weirs or small waterfalls to limit the work of constructing an artificial one. Finally, proximity to the house(s) is an important selection criterion as well. The closer to the house, the lower the costs for cables and the shorter the distance one has to cover to check the unit.

A last remark about the place of installation is related to sharing of the water resources for other purposes and with other users of pico-hydro. Water resources are very important in rural areas of Laos, because streams and/or rivers nearby villages have multiple functions, such as washing, cleaning, transportation and fishing. Pico-hydropower users have to take these into account when installing their units. However, all interviewed people indicated that it was possible to combine power generation with other river functions without generating conflicts. Still, the number of available sites is sometimes limited and, as mentioned before, some sites offer more favorable conditions than others. Usually, this problems is ‘solved’ by a first-come-first-served system, where at some point villages run out of viable spots for pico-hydro units.

There is a lot of skill involved in the installation of pico-hydropower systems. Although there are certain tricks which can be seen at many installations, all sites offer specific possibilities and challenges. Besides the very necessary parts, the pico-hydro unit and the cables, the 'civil work' are usually carried out with locally available materials. Although the selection of the site is not always easy, people usually find creative ways to make their system work. Sometimes even irrigation channels are used to install pico-hydro units (see intermezzo).

Intermezzo: Pico-hydro systems in irrigation channel

A special type of pico-hydro site can be found in Moh village, Kham district, Xieng Khouang province, where pico-hydro units are placed in an irrigation canal. The construction of the irrigation scheme and the two meter wide concrete canal running through the village was finished in 2003. The government was responsible for initiating this project, executed by a Vietnamese construction company. The canal is used to provide water to the fields adjacent to the village. No engines are necessary to pump the water, because simple plastic pipes and gravity can do the job. Another use of the irrigation canal is water supply and bathing. The third usage of the irrigation canal is to generate electricity using pico-hydro. At points where there is sufficient head in the canal, people have constructed small dams to channel the water through their propeller pico system. Poles and wires along the canal transport the electricity to the households. Interestingly, the irrigation canal was not made for pico-hydro and this use was not envisioned at the time of design and construction. There are also pico-hydro systems to be found in the stream running nearby the village. Installing pico-hydro units in irrigated rice paddies is known in Vietnam as well (ESMAP, 2005)

Figure 17 - Irrigation channel in Moh village, Kham district, Xieng Khouang province

Figure 18 - Pico-hydro unit in irrigation channel in Moh village

Seasonality

Pico-hydro units cannot be used all year around in many areas, because of fluctuating availability of water during the year. This change of seasons has different effects on each kind of sites in different terrains and accompanying types of installations. Pico-hydropower units do not generate enough power when there is too little water and are in danger of being swept away when there is too much of it. In general, the water flows in Laos are very dependent on seasonal fluctuations: the dry and rainy season. The Mekong, the largest river running throughout the country, transports five times as much water at the end of the rainy season compared to end of the dry season. Similar kinds of fluctuations are common for other rain-fed rivers and streams in Laos as well. However, those river or streams that are mostly spring-fed are much less sensitive to these changes.

Table 2 - Generalized classification of terrains, water resources and seasonality

Terrain	*Type of water resource*	*Main water source*	*Seasonality effects on pico-hydro*	*Area in report*
Mountainous	currents and streams	Spring-fed	Usage all year around	Mai and Kuah districts, Phongsali
Hilly	Streams and small rivers	Spring- and rain-fed	Cannot use in rainy season (May to September)	Kham district, Xieng Khouang
Flat	Rivers	Rain-fed	Cannot use in rainy season (May to September)	Viengthong district, Bolikamxay

In **Table 2** you can see a highly generalized overview of available terrains, water resources and effect of seasonality on pico-hydro use in Laos, although many variations exist. Areas in the mountainous north, such as Phongsali, have more spring-fed water flows, whereas the central and southern part of the country, e.g. Bolikamxay, have bigger and mostly rain-fed water resources. The former areas are thus generally less sensitive to seasonal changes when it comes to water flow. This affects the place where people install their pico-hydro unit and the way they use it as well. In those areas with rain-fed streams and rivers, people have to take out their pico-hydro unit in the rainy season (roughly from May to September), whereas people using spring-fed currents do not have this problem. For example, the time that people cannot use their pico-hydro varies from the whole rainy season to just one or two months. Sometimes the situation is inverted, i.e. people have to take out or move their pico-hydro unit in the dry season due to lack of water.

Cables

The electricity cables are probably the most dangerous part of the pico-hydropower system, because of unprotected cables and damage to the improvised pole constructions. The cables are used to transport the electricity from the pico-hydro unit to the house(s). The length of these cable ranges from 20 meters to more than 1.5 kilometer. In the latter case, the cable quickly becomes the most expensive part of the investment of a pico-hydropower system. The quality of the cables used is highly variable. In most villages visited for this research, people used wires with plastic insulation. However, some cases of cheap unprotected wires were observed as well. Besides the dangers of touching them, these cables are also more difficult to see. VOPS pico-hydro safety instructors indicate that the usage of uncovered cable varies from 30 to 60% in the areas they were working (interviews 37, 44, 45 and 47). Moreover, some people use cables with a small diameter, which can lead to considerable loss of voltage in the cable.

There are two main ways in which the cables are put up. Some people use poles made out of bamboo or wood to connect their cables. In other cases, people just hang the cable in the trees or bushes. In both cases, the cables can lead to dangerous situations, because they are often hung very low, making it easy to touch or break them when walking or driving by. Moreover, the cables tend to break, when there is a storm for example.

Figure 19 - Broken cables at Thadeua village, Viengthong district, Bolikamxay province

Figure 20 - Cables at Muang Muan village, Viengthong district, Bolikamxay province

The use of pico-hydropower is known to have caused casualties and even deaths. Although there are no official figures about the number of accidents, there are numerous stories of villagers and experts about deadly accidents caused by electrocution. Also, during the field work of this research, these kinds of stories came up. The main causes are probably a lack of knowledge about the dangers of electricity and unfortunate accidents with loose cables. However, the situation is said to have improved over the past few years. The interviewed Associate Professor of the National University of Laos thinks that this is because people have heard the stories and know better about the dangers of electricity now (interview 13). The field observations confirm this trend, because in the large majority of the cases, insulated cables were used. This points to a tough learning effect, but also to the persistence and value of the functions of electricity for people.

Functions of pico-hydro electricity

The most important functions of pico-hydropower electricity are light and entertainment. Although there are some other technologies for people in off-grid areas in Laos to produce electricity, most of these function can be performed by pico-hydropower as well. Both the uses of pico-hydropower and these other technologies will be compared. First, the results of the surveyed villages are shown in **Table 3**.

Table 3 - Figures about pico use and applications in studied villages

Province	District	Village	Households	Nr. Pico	Pico/ hh	TV (& CD)	TV/hh
Bolikamxay	Vieng-thong	Mouang Muan	46	23	50%	0	0%
		Thadeua	140	50	36%	1	1%
		Piengton	59	45	76%	0	0%
	Average villages Viengthong		82	39	54%	0	0%
Xieng Khouang	Kham	Moh	38	23	61%	12	32%
		Khaivieng	68	55	81%	14	21%
	Average villages Xieng Khouang		53	39	71%	13	26%
Phongsali	Mai	Sop Nhao	85	49	58%	12	14%
		Sop Poun	84	60	71%	15	18%
		Huay Wang Khao	42	30	71%	20	48%
		Sen Art	51	26	51%	7	14%
	Kuah	Huay Phae Ou	45	40	89%	25	56%
		Taang Kok	31	10	32%	5	16%
	Average villages Phongsali		56	36	62%	14	28%
Average of studied villages			63	37	61%	10	20%

The first and main application of electricity generated by pico-hydropower is to provide light. All pico-hydro units that were studied for this research were connected to at least one or more light bulbs. For many households using pico-hydro, lighting is also the only use of pico-hydro. In the three village surveyed in Viengthong district, Bolikamxay province, for example, all but one of the households used pico-hydropower for lighting purposes only. Light is also one of the only possible function if people share one unit. Sometimes people buy the unit together and use equal shares of electricity, but in other situations people share part of their electricity with family or neighbors, sometimes asking them for a monthly fee or help with the construction and maintenance of the unit.

People use the light at night for dinner, to find their way to the toilet, to do housekeeping, for reading, homework and income generating activities (e.g. weaving and making bamboo mats, see **Figure 21**). In addition, people charge small batteries with the pico-hydro units and then use in flashlights (e.g. for catching frogs). Finally, those houses with light tend to become places for social gatherings, where people meet, talk and drink.

Figure 21 - Men and women preparing bundles of garlic after sunset using light from a pico-hydro unit, in Huay Wang Kao village, Mai District, Phongsali

Most people in rural areas use energy saving light bulbs, because these sometimes use as little as 7 Watts. However, voltage fluctuations, caused by floating branches getting stuck in the propeller for example, can lead to burning out of light bulbs (sometimes up to three light bulbs a month). Energy saving light bulbs are particularly vulnerable to this. Of course, this figure depends a lot on the quality of the bulbs, the quality of the pico-hydro unit and the place of installation. It is not uncommon for people to use a lower number of light bulbs in the dry season, because of there is less water and therefore less power during that period of time.

Traditionally, people in the villages use firewood and diesel lamps for lighting. Saving time to collect firewood, saving diesel costs and reducing smoke in the house are some of the collected motivations from interviews to use pico-hydro instead of wood or diesel. An alternative way to produce electricity instead of pico-hydro power is to use a generator, solar panel or car battery. Generators are expensive, both in purchase and in use, but generally offer more stable electricity. Solar panels are very expensive, not everywhere available and require the use of a car battery as well. In some areas car batteries are widely used and can be charged at a central point in an (adjacent) village. However, this is not the case in the districts surveyed for this research. For example, only the village leader in Mouang Muan, Bolikamxay, was using a battery and paid about four times the regular price to charge it in other areas.

Entertainment is the second most important use of electricity from pico-hydro in the three fieldwork areas of this research. Entertainment devices are mainly television, CD-player and Video CD (VCD)-players. Radios are also used, but these are commonly powered by batteries. **Table 3** shows that the percentage of households with televisions in the case studies is highly variable, but on average 20% of the surveyed households uses one. The number of CD and VCD-players is roughly the same, because people try to acquire a complete set of entertainment devices. On television, people watch a limited number of channels, including those of neighboring countries, such as Thai soap operas. In order to receive these channels, people must own a satellite dish. CD and VCD are used for listening to music and to play karaoke VCDs. Similar to light, houses with entertainment sets are also likely to become places with a lot of social activity, such as meetings and gatherings. And since the number of places with entertainment devices is more limited, this effect is stronger.

The problems with voltage fluctuations are more critical when using entertainment devices than light bulbs, because they are much more expensive to replace. Therefore, some people use voltage protectors. These devices, produced in China, check the voltage and disconnect the power to the devices when necessary. Despite these additional measures, some people in the areas visited still reported broken entertainment devices. Yet, others claim that regulators are actually not necessary, because before installing them, they did not have problems either (Interview 34).

Alternatives for the power needed for entertainment devices are fairly similar to those already mentioned in the previous section on lighting: car batteries, solar panels and generators. Provided that a pico-hydropower unit delivers electricity of decent quality, it can be used for longer periods of time compared to batteries and solar panels (which are also connected to batteries to deliver AC-power). People in the surveyed villages sometimes use a generator next to their pico-hydro unit for entertainment purposes. Generator are available all year around and produce a stable output of electricity. However, the use of diesel puts considerable pressure on the budget of most households in Laos.

Figure 22 - Satellite dishes at village in Kuah district, Phongsali

Figure 23 - Entertainment set, including voltage stabilizer in Khaivieng village, Kham district, Xieng Khouang province

Besides light and entertainment, there are a few other uses of pico-hydropower, such as mobile communication, battery charging and for fans. Mobile network coverage is expanding rapidly over the Lao countryside and being electricity from pico-hydropower enables people to charge their mobile phones. This could improve their family relations, but also give access to information that would otherwise take more time to obtain. Batteries can be charged as well with a proper voltage regulator and a battery charger. Batteries provide electricity for those who do not have their own pico-hydro unit or they can be connected to a flashlight for mobile use. Pico-hydropower electricity is also used for fans. A fan is useful when the weather is warm. In addition, the air circulation helps to keep mosquitoes away and therefore plays a role in the prevention of disease (World Bank, 2006).

Some functions cannot be fulfilled by low-head propeller pico-hydropower units, because they require too much power, such as electrical saws and rice mills. Also water boilers, rice cookers, refrigerators and the like are problematic because of the high power demand. Computers were not observed nor mentioned in interviews in the villages surveyed, but there is in principle no problem to connect these to pico-hydro systems with stable voltage output. Laptops would be particularly suitable, because of the low power demand and a transformer and battery is included. If the use of pico-hydropower could be successfully used to power computers, important new function would be added.

At present, however, light and entertainment are the two most important functions of electricity generated by pico-hydropower. Especially electrical light is a very important asset for people otherwise dependent on diesel lamps or firewood for light from 6 o'clock in the evening onwards. Entertainment is an important additional asset to the livelihoods of people in Laos and brings modernity to the remote rural areas in the form of soap operas, but also information about other parts of the country and the world. Because of the important functions and the limited alternatives, people usually take good care of their pico-hydro system and maintain it regularly.

Maintenance and repair

The maintenance of a pico-hydropower system is labor intensive and has to be done very regularly. Most interviewed respondents indicate that they clean and check their systems every day (Figure 24 and Figure 25).

Figure 24 – Checking pico-hydro unit in the Nam Muan river, Bolikamxay province

Figure 25 - Checking pico-hydro nearby Sop Poun village, Mai district, Phongsali province

Cleaning consists of taking out branches, leaves, garbage and fish that get stuck in the propeller. Of course, this has adverse effects on the functioning of the unit, but it can also lead to damage of the pico-hydro or connected appliances, because of the voltage fluctuation. Most people also run a regular check on parts of the pico-hydro unit and the cables, because some parts can wear out quickly and the cables are fragile. As mentioned before, people sometimes place small nets or grid in the current to prevent too much material getting into their pico-hydro turbine (**Figure 26**).

Besides daily cleaning, people sometimes choose to stop or take their pico-hydro units out of the water during the day. In this way, the vulnerable parts wear out less quickly, some cleaning can be avoided and it can prevent the risks of electrocution. In some areas, people stop the turbine by closing a small gate and thus stopping the water first (Interview 45). However, in most cases people just stop the turbine with their bare hands. In Vietnam, people are take out their pico-hydro-units sometimes to prevent theft as well (ESMAP, 2005). People in the field work areas of this report did not have to do this, although some said they use locks for the same purpose.

Many people interviewed in the target areas indicate that one of the disadvantages of pico-hydro is the maintenance required. For example, if the lights go out during the evening, someone has to go to check what is wrong. This is not very easy and pleasant in the dark, especially when the unit is far from the house. One of the tricks that people reportedly use, is to short-circuit their system at home when the electricity breaks down. By doing so, sometimes, the problem can be solved remotely, albeit not in a very safe way (Interview 13).

Figure 26 - Bamboo grid in Huay Phai Ou, Kuah district, Phongsali province

Figure 27 - New windings for pico-hydro unit

If there is a problem with the pico-hydro unit, people always try to fix it themselves or get help in their village first. In the areas studied for this research, none of the people were given warranty when they bought their units. However, if they cannot carry out the repair by themselves they sometimes go back to the shop to ask for help. Most of the time the problem relates to one of the vulnerable parts: windings, bearings or propeller have to be replaced (Figure 27). These can be bought at the shops selling the units.

Conclusions about use of pico-hydropower technology

The detailed description of the networks around the users of pico-hydro systems in Laos shows the importance of the technology for livelihoods in remote rural areas and the skill and creativity involved in installing and maintaining their unit. Geographical factors play an important role in the construction that villagers use and the use throughout the year. The skill to install the system in a place to maximize the head and flow and to minimize the length of the cables is passed on in and between users by word of mouth. Although there is a lot of work involved in maintaining and repairing the system, the benefits apparently outweigh this burden. The most important benefits of pico-hydro electricity are to provide light for cooking, safety, dinner, small production activities and to make homework at night. In addition to light, some people can connect entertainment devices, such as a TV or a VCD player, to their system as well. These benefits explain the driving force behind the networks of the market to provide the units to the villagers. Compared to other technologies, pico-hydropower matches the functions of solar panels and diesel generators, but does so at much lowest costs as will be shown in the next section.

4. Financial analysis of pico-hydropower systems

Pico-hydropower is the cheapest source of electricity generation in off-grid areas in Laos. In this section it will be shown that the initial investment costs of pico-hydro systems are less important than the additional costs of maintenance and repair. Furthermore, pico-hydro systems are currently competitive or even cheaper than the subsidized solar home systems which are being rolled out by VOPS and Sunlabob in Laos. Outside Laos, figures on energy systems throughout the world show that pico-hydro is by far the cheapest source of electricity generation as well.

Collected financial data

Table 8 shows the cost, variation and assumed lifetime of different components of a pico-hydropower system in Laos, using data collected in the field triangulated by the Entec (2000) and ESMAP report (2005). Because of the difficulty to collect reliable figures and the high variability sometimes, only very basic financial analyses are applied. For example, no discount rate has been used and only one exchange rate from Lao Kip to US Dollar has been applied. [3]

Table 4 - Overview of components of economic analysis based on average market prices

Part	*Specific*	*Amount[4] (USD)*	*Variation (USD)*	*Est. lifetime*
Pico-hydro unit	300W	22.8	21.5-28	3 years
	500W	28.7	26-30	3 years
	1000W	67.3	66-70	3 years
Cable	Price (100m)	7.5	5-11	10 years
	Length	500 m	50-1500m	-
Spare parts	Bearings	1.4	1-3	2.5 per year
	Windings 300W	11.0	9-13	2 per year
	Windings 500W	14.4	12-16	2 per year
Light	Energy saving bulb	0.8	0.6-3	3 months/bulb

A couple of remarks have to be made about the table, because some of the figures are highly variable and others are difficult to make a reliable estimations on. Wherever possible the average prices collected at the markets were used. Although the prices collected from the users in the villages are fairly similar, they are more difficult to compare because of time since purchase and inflation since. Prices cited by some users might also be exaggerated, depending whether they bought the product from a shop or middle men.

The data themselves also require some explanation. Most important was the difficulty to make assumptions about the lifetime of the components, notably about the unit itself. Some people claim not to have replaced their pico-hydro unit in more than ten years. Empirical data from this research

[3] 1 US Dollar = 10.000 Lao Kip (exchange rate January 2008). Before January the dollar was worth more than this, but has been steadily falling after.

[4] This amount is the estimated amount based on the weighted average of the data collected

indicates that few of the respondents have ever replaced their unit and it is more common to buy spare parts. This contradicts information from Entec (2000) and ESMAP (2005). Secondly, there are different types of pico-hydropower units. The range of prices is, however, not very big, indicating that the market is highly competitive. There are, for example, only slight differences between prices at the market in border town Lak Xao and the more inland market in Phonesavan. The opposite is true for the parts like bearings, light bulbs and, to a lesser extent, windings. For these parts, there is often the choice between more expensive products and cheap ones. Finally, the length of the cables becomes the most expensive part of the initial investment if the pico-hydro unit is more than a few hundred meters away from the house. There is, naturally, a high variability in the distance of a house from the pico-hydro unit.

Lifecycle costs of pico-hydro systems

The total costs of a pico-hydropower system in the field work areas depends mainly on the costs of cables and the annual expenditures on spare parts and light bulbs. By progressively adding different cost elements to the financial analysis, the most influential variables are revealed. The cables are the most expensive investment costs of a pico-hydro system in case of long distances to the house. Figure 28 shows the investment costs based of different sizes of pico-hydro units and different cable lengths based on average prices as cited in

Table 8. It is shown that the investment costs of the turbine itself can become relatively small compared to the cost of cables. It also shows that the biggest unit, rated at 1000 Watts is more than twice as expensive as the 500 Watts turbine. An often heard explanation for this from shopkeepers interviewed is that the 1000 Watts units are better quality than the smaller ones.

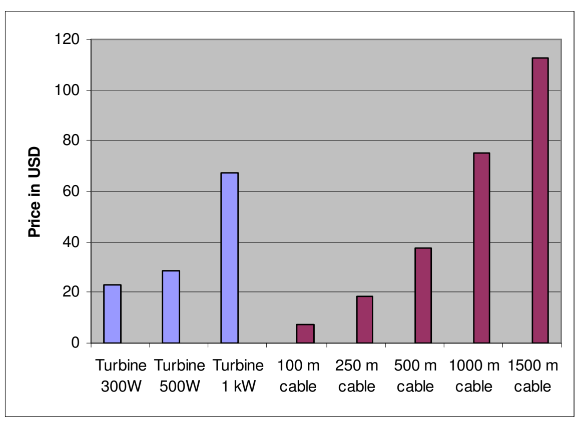


Figure 28 – Average investment costs for different turbines and cable lengths

500 Watts pico-hydro systems are more expensive on annual basis than 1000 Watts systems, because of the higher frequency of replacing spare parts. Figure 29 shows the annual costs related to the use of different types of units, again using the data from Table 8. The costs for a new turbine or new cables are divided by the average lifetime, to determine the average costs per year. This makes it easier to compare, although it is not in line with the way people spend money in reality. The most striking conclusion is the amount people spend on replacing windings and bearings. These

together are easily the biggest average annual expenses. From individual interviews and the surveys at the market, it becomes clear that there are no spare windings for the 1 kW pico-hydro turbine, probably again due to the higher quality of this size of unit. This has, however, big consequences for the annual expenditures and makes the 1 kW rated unit cheaper than the 500 watt unit on an average annual basis. Furthermore, it has to be noted that the price of the cables, which is one of the biggest investment costs, does not have a major impact on the average annual costs, because the assumed lifetime is long (10 years)[5].

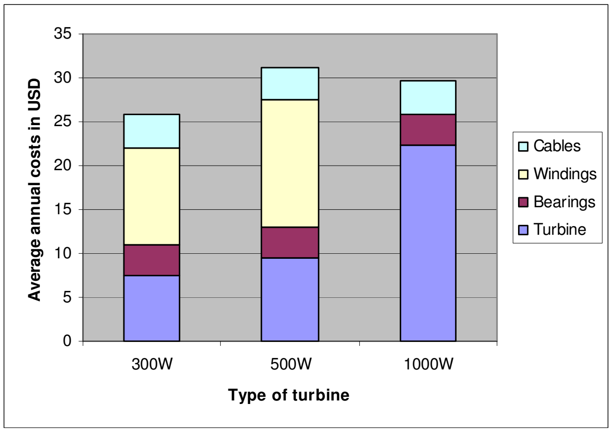
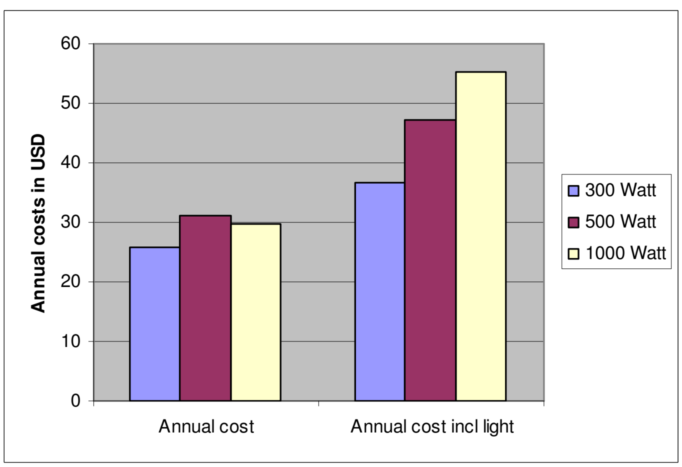


Figure 29 - Average annual costs for different turbines, broken down into different parts

Replacing light bulbs can also add considerably to the average annual costs of pico-hydro systems. Figure 30 also includes the costs of replacing light bulbs that break due to unstable voltage output. Although these figures are not definite, it still shows how much impact this kind of expense has on the average annual cost if light bulbs have to be replaced every three months. Because it is assumed that more light bulbs will break if there is more capacity, the 1 kW turbine surpasses the 500W turbine again on average annual costs.



[5] Cables do break regularly, but this can be repaired or only small parts have to be replaced

Figure 30 - Average annual costs of different types of pico-hydro including light bulbs[6]

The crude financial analysis of pico-hydropower shows that the total costs of the system have to be taken into account in order to be able to compare between different low-cost low-head pico-hydropower systems. This shows that the distance of the unit to the house, the replacement of vulnerable parts and light bulbs are the most important cost components on average annual basis. These analyses can be used to compare pico-hydropower in the field work areas with findings from other countries and other electricity generating technologies.

Comparisons with other countries and technologies

Different comparisons show that pico-hydropower is the cheapest technology when compared to other stand-alone conventional and renewable energy technologies. The first comparison is between the pico-hydro findings of this study and those in Vietnam, because the countries and the type of pico-hydro units used are quite similar. The ESMAP report (2005) estimates that the initial investment for a low-head pico-hydro system from China (rated 300W), including civil works, transmission lines and household electrical system, is between $65 and $190.[7] In comparison, findings from Table 8 show that in Laos a similar pico-hydro system costs between $29 to $138 in terms of initial investment for similar expenses.[8] However, analyses from the previous sections indicate that installation costs are not the most important over the lifetime of a pico-hydro system. The ESMAP report does not make a full lifetime analysis of the low-head Chinese pico-hydro unit, but only for a more expensive 200 Watts unit. The life-cycle cost of this unit in Vietnam is estimated at $74 to $150 per year. This is considerably higher than the estimated annual costs of $44 - $55 calculated using the data assembled of this research.

Pico-hydropower is cheaper than the solar home systems offered by VOPS and Sunlabob in Laos without taking subsidies into account (Table 5). The solar home systems are distributed by two different organizations in the country. The first one, Sunlabob, is a private company selling and renting out renewable energy devices. The second one, Village Off-grid Promotion and Support (VOPS), is an organization supported by the Ministry of Energy and Mines and the World Bank, offering 100% capital subsidy on the panels. Both of the organizations offer complete solar home systems (panel, controller, battery, electric system and light bulbs) for a monthly payment. Including the subsidy of VOPS, their costs are comparable to pico-hydropower although they provide a much lower power output. Sunlabob's private systems are more expensive, even though they use a payback time of 20 years. Only the initial investment in these solar home systems are considerably lower than that of a pico-hydropower system. In addition and contrary to the expectations, solar home systems have not become much cheaper over the recent years (IFC, 2007). It can therefore be expected that pico-hydropower stays cheaper at least in the near future.

[6] Assumed amount of light bulbs per house per type of unit: 3 (300 W), 5 (500W), 8 (1 kW)

[7] High variability mainly caused by the (unknown) length of the cables ($20-100).

[8] For a cable length of 50-1500 meter, with installation costs set at zero.

Table 5 - Comparison solar home systems and pico-hydropower in Laos (adapted from DGS, 2006)

Type	***Provided by***	***System***	***Watt-peak (W)***	***Initial investment ($)***	***Average monthly costs ($)***
Solar home system	Sunlabob rental (Interview 57)	Panel, charge controller, battery, electric system)	20	10	3.5
			32	10	4
			50	10	5
			75	10	9
			100	10	13
	VOPS, 10 years leasing (VOPS, 2007)	Panel, charge controller, battery, electric system)	20	16	1.8-2.5
			30	19	2.3-3.0
			40	22	2.9-3.6
			50	25	3.5-4.2
Low-costs pico-hydro	Traders (Table 8)	Turbine, cables and light bulbs	Rated 300 W	63	2.1
			Rated 500 W	70	2.8
			Rated 1000 W	111	2.4

Pico-hydropower is also cheaper in comparison with other electricity generating technologies in the world. Figure 31 presents a comparison between small-scale solar, wind, pico-hydro and diesel generators. It shows the costs at the time the World Bank study was published, 2004, as well as the expected costs in 2015. This figure shows that both the 300 and the 1000 Watts pico-hydro provide the cheapest electricity per kilowatt-hour, also in the future. The two options that are closest to pico-hydro both use wind energy and are therefore not very relevant in the context of Laos, because of the limited potential in the country. It should be noted that the use of cost per kWh can be deceiving, because pico-hydro can deliver power all day long without much use. Diesel generators, on the contrary, are only used when the electricity is really needed. Therefore, other methods might be more appropriate to compare pico-hydropower with other technologies.

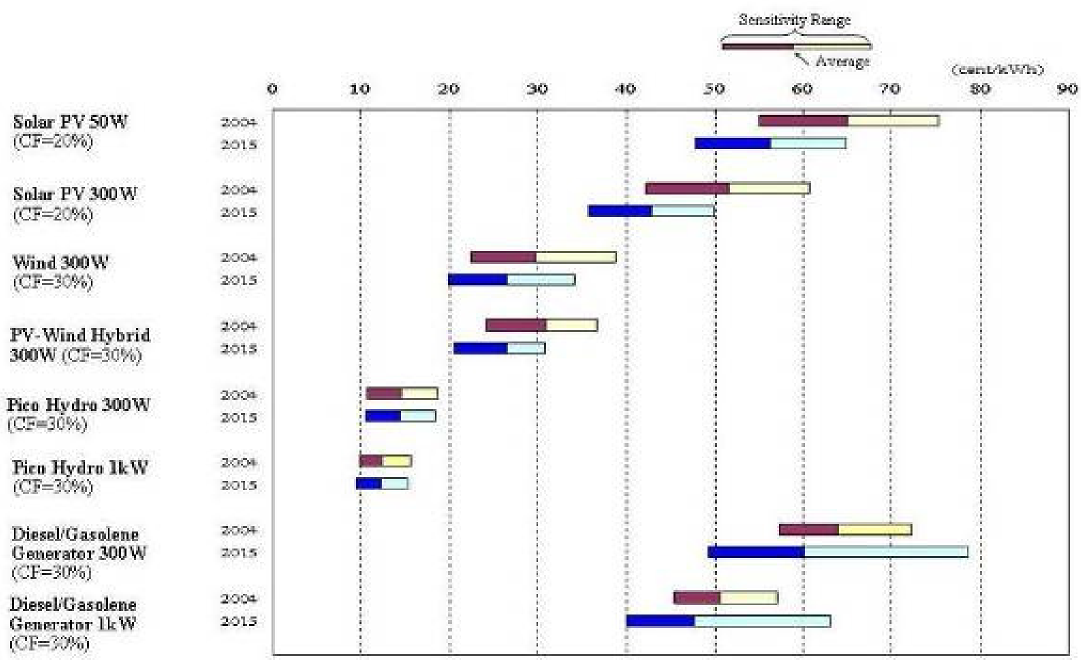


Figure 31 - Comparison of different off-grid electricity production systems (World Bank, 2005)

A better method to compare energy technologies can be found in ESMAP (2005), which includes comparisons with several different off-grid electricity production options (Table 6). The pico-hydropower figures from Laos are added to show that there is a big difference between the ESMAP-figures from Vietnam and those found in this study. The main reason for this difference is the lower equipment costs, because the *family pico-hydro* mentioned in the table refers to a more expensive pico-hydro system than the low-cost Chinese or Vietnamese technology found in Laos. In addition, for *Pico-hydro in Laos* zero installation costs and lower operation and maintenance costs are used.

Table 6 – Comparison of different off-grid electricity production systems (table from ESMAP, 2005; own data inserted in grey beam)

Technology	*Capacity (no. hh)*	*Lifetime*	*Equipment cost over lifetime ($)*	*Installation cost ($)*	*Operation & maintenance cost per year (est.) ($)*	**Life-cycle cost ($/year per hh)**
Pico-hydro in Laos[9]	(rated) 300 W (1 hh)	3 years	29-138	0	25	35-71
Family pico-hydro	200 W (1 hh)	5 years	80–200	40–300	50	74–150
Community picohydro 3,000 W (15 hh)	220/110 V AC	3,000	Varies:	1,000–3,000	200	~31–40
PV-solar home system	100 Wp (1 hh)	20 years	600–800	200–600	100	140–170
Small wind (China)	300 W (1 hh)	15 years	800	300	80	153
Small diesel/ petrol gensets	1–3 kW (1–3 hh)	110 years	1,000–5,000	100–350	40–400 (depends on hours of use)	150–311

Conclusions financial analysis pico-hydropower

Pico-hydropower is the cheapest source of off-grid electrification technologies, according to the data collected and the comparisons made. The initial investment costs are very low, but even when taking the additional costs of maintenance and repair and broken light bulbs into account, the technology still has the lowest life-cycle cost. However, each of the technologies has its own characteristics, advantages and disadvantages as outlined for pico-hydro in the previous section. Moreover, the relevance of these comparisons is at present not very high, because for people in off-grid areas of Laos there are not many options to choose from. In fact, besides in those areas in which Sunlabob and VOPS are supporting solar home system implementation, pico-hydropower and diesel generators are the only types of electricity generating technologies available. Moreover, the fact that there are existing networks of pico-hydro sales, is likely to influence decision-making.

[9] From data collected for this research

5. Conclusions

Pico-hydropower is, with an estimated 60.000 units in the country, a very important and widely used electrification technology that plays an important role in the livelihoods of people in off-grid rural areas of Laos. This can be concluded at least for the areas surveyed, but it is likely to be similar in comparable areas as well. The technographic descriptions in the chapter show the variety of different actor-networks involved that all contribute to the hybrid socio-technical system of pico-hydropower in Laos. These networks are summarized in Figure 32.

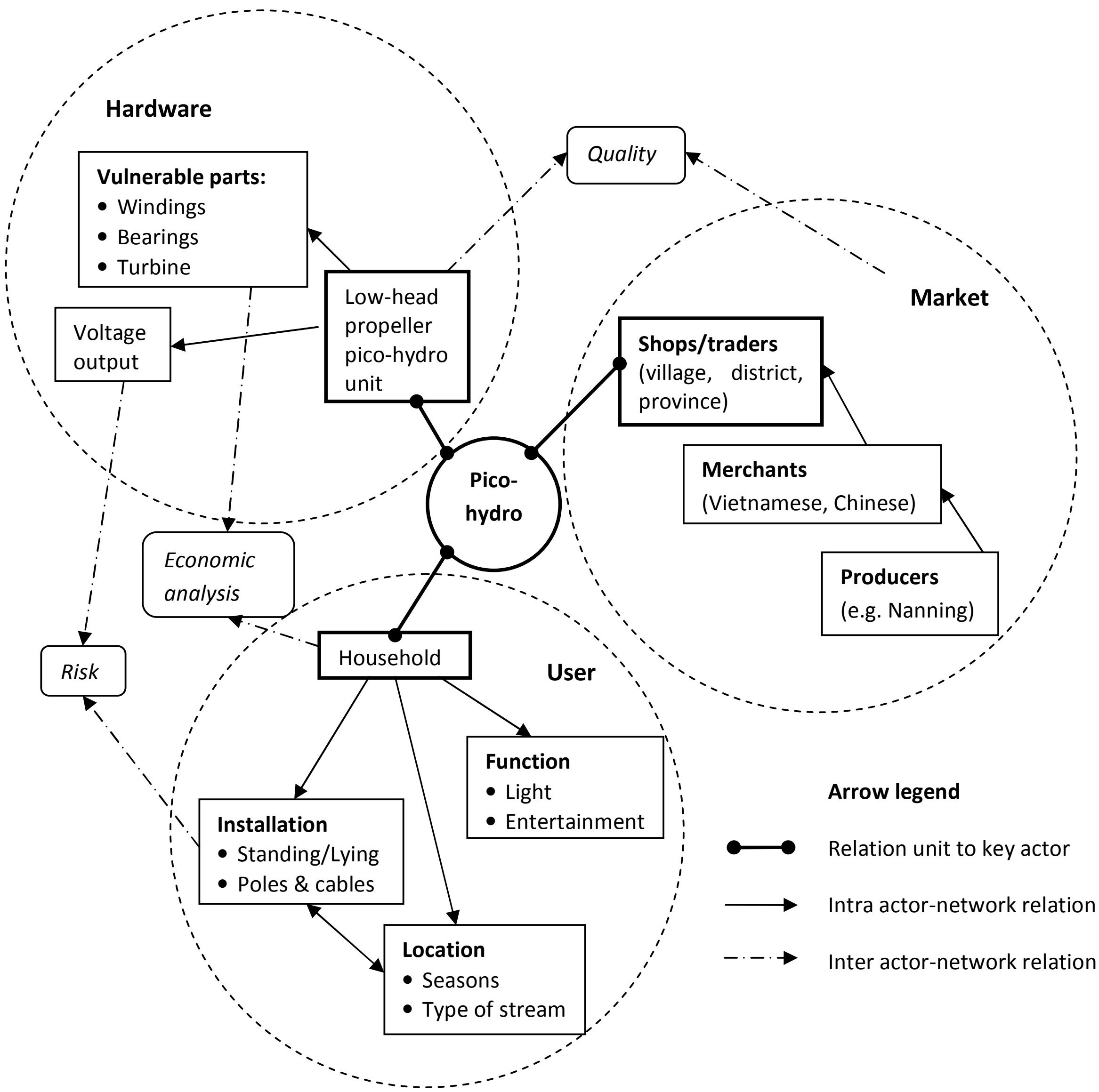


Figure 32 - Actor-networks of pico-hydropower technology in Laos

The figure shows the three different sections of this chapter: *hardware, use* and *market* and shows the most obvious links. Of course, this picture cannot capture the detail and the complexity of the interactions that have been touched upon in the chapter. However, it gives an indication of the complex networks that have been formed over the past twenty years around pico-hydropower technology.

Driven by the demand for electricity in the off-grid rural areas and the ability to produce cheap hydropower technology, this network has gradually taken shape to become what it is now. Different production facilities have been set up in China and Vietnam to meet the demand that has risen in their own countries and Laos. Traders, crossing the borders regularly to sell all kinds of products, have seen the market potential for pico-hydropower and started delivering systems to markets in large cities and small villages, even in the far outposts of Laos. Villagers in off-grid areas, keen on reaping the benefits of modernity, such as electric light and television, but constraint by their small budgets, started buying pico-hydropower to improve their livelihoods, especially at night. The focus on low-cost solutions have lead to the development of inventive constructions using locally available material whenever possible. However, this low-cost orientation in Laos and Asia in general has led to low quality hard to trace equipment, which needs regular repair and maintenance and can even leads to dangerous situations. Yet, there are indications that people learn to mitigate these risks and problems of, for example, voltage fluctuations and frequent breakdowns. This technography is a first attempt to bring all these developments together in a systematic description that does justice to the complexity of the natural and social interactions around pico-hydropower.

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Annex I: Electricity situation of Lao PDR

Overview, biomass and fossil fuels

The production of electricity and hydropower in particular are important for Laos, because the country has very limited access to fossil fuels and other sources of energy. Electricity from hydropower is booming, but the electricity generated in this way will mainly be used for export. Electrification of the rest of the country is becoming increasingly difficult and centrally planned off-grid solutions are not very successful so far. Household electricity generation is a popular way in off-grid areas to get access to electricity, but difficult to capture in the national statistics.

Most of the people in Laos, especially in rural areas, still depend mainly on fuel wood and charcoal for household energy consumption, such as cooking and heating. This fuel wood and charcoal consumption is about 0,75 m^3 per capita per year, thereby making up for 69% of the average energy use in the country (ADB, 2006b). Energy that is needed for transport comes from imported fossil fuels, amounting to 485 million liter per year and is expected to rise by 10% annually. Although explorations are still going on, there are no oil and gas reserves found in the Lao PDR yet (LIRE, 2008). Other fossil fuels are also only available in limited quantities. There is a current production of 130,000 tons of coal annually and there are currently unexploited, although economically recoverable, reserves of brown coal (lignite) in the country (DGS, 2006). Another difficulty is that Laos is a land-locked and has to transport imported fossil fuels over land.

Electricity production

Electricity is a source of energy which is more abundantly available in the country and is mostly by generated by large hydropower plants. The mountainous terrain and the Mekong with its many tributaries renders the country very suitable for this type of electricity generation. shows the total installed capacity for electricity generation in the country, according to the latest official publication of the Ministry of Energy and Mines (MEM, 2005). The importance of ‘small to large’ hydropower becomes clear from the 99,62 % of the electricity generated in this category. The table also shows that the total installed capacity of this type of hydropower is currently ‘only’ 669 MW, whereas the estimated potential of the country is much higher. This potential used to be quoted at 23,000 MW (UNDP, 2006), but the Government of Laos has recently increased this number to 30,000 MW (Vientiane Times, 10-01-2008). This, and the fact that the GoL has approved some preparatory studies for dams in the mainstream of the Mekong, indicates that the ambitions to expand dam construction are far-reaching and even include the previously rendered undesirable mainstream Mekong dams (Baird, forthcoming).

Table 7 - Total installed capacity in Laos (MEM, 2005)[10]

Ownership	***Small to large hydro >1 MW***	***Mini hydro 100 kW – 1 MW***	***Micro hydro 1 – 100 kW***	***Pico hydro <1 kW***	***Diesel gen.***	***PV Solar***	***Total installed capacity***	**Percent**
	kW	kW	kW	kW	kW	kW	kW	%
EdL	307,548	-					307,548	45,81
Province	1,200	951	454		860		3,465	0,52
IPP	360,000						360,000	53,63
Other	-					297	297	0,04
Total	668,748	951	454		860	297	671,310	100,00
Percentage	99,62%	0.14%	0.07%		0.13%	0.04%	100%	

One of the first examples of these ambitions is the Nam Theun 2 hydropower dam in Khammouane province. The construction of this dam has received worldwide attention for its size, impact on people living in the construction and basin area and its environmental impact. The dam is set to be finished in 2009 and will generate 1070 MW of electricity, flood an area of 450 km^2 and directly affect 6,200 people living in the area. Although the Nam Theun 2 dam will add considerably to the current electricity generating capacity, it is certainly not the only big hydropower project underway. The Lao government keeps a public list of electric power project projects that are in some stage of development (GoL, 2008). On the list of April 28, 2008, there were 62 projects in progress, all but a few on hydropower (bigger than 1 MW).[11] These projects are mainly financed and executed by foreign companies, but the Lao government typically has around 20-25% of the shares in each of these project, sometimes directly, but also through the Lao Holding State Enterprise (LHSE) or the national utility EdL. The projects that are currently under constructed, including the Nam Theun 2, amount to 2,100 MW (Vientiane Times, 10-01-2008), but the GoL's aim is to have 6,000 MW installed by 2020 (UNDP, 2006). If all the projects that are currently on the list of the government would be finished, including seven projects in the mainstream Mekong, the total installed capacity of

[10] This table is a direct copy from the *Electricity Statistic of Lao PDR: 2005* (MEM, 2005), only the lower row of percentages has been added. The blank spaces are also blank in the original document.

[11] Not all project explicitly state that they are on hydropower, but there cannot be more than a few that use other sources of energy.

small and large hydropower would be over 20,000 MW. This would turn Laos in the role envisioned by the government: the 'battery of Asia' (Vientiane Times, 30-10-2007).

Several people are concerned by these far-reaching ambitions of the government for large dam development, related to their negative impacts Large dams have been widely criticized in general for their negative impact on the local environment and population. According to these critics, the benefits of large dams are often overstated and costs systematically underestimated. Moreover, large dams have serious impacts on the basins where large eco-system disruptions take place and people have to be resettled. Especially the process of resettlement leads to the impoverishment and socio-cultural and psychological stress. Furthermore, the basins itself are claimed to increase greenhouse gas emissions and water-borne diseases (Jobin, 1999; McCully, 1996; Scudder, 2005). Also in Laos, there has been substantial criticism on the far-reaching plans for large hydropower development (e.g. IRN, 2008; Baird, forthcoming). While the government in Laos managed to keep the construction on the Nam Ngum dam in 1971 silent during the turbulence surrounding the war (Hirsch, 1998), the construction on the Nam Theun 2 and the other plans did not go unnoticed. Apart from the negative effects already mentioned, high corruption, the absence of civil society organizations and free press and limited transparency are usually mentioned as the key points of concern (e.g. IRN, 2008).

Export of electricity

Despite the criticism, large hydropower will play an important role to boost electricity as export product for Laos in the future, because only a small proportion will be used domestically. Figure 33 shows that already about half of the current total amount of electricity produced is exported, mainly to Thailand. In addition, the total generation has gone up over the past 15 years, whereas the export remained relatively stable, meaning that the domestic demand is rising.

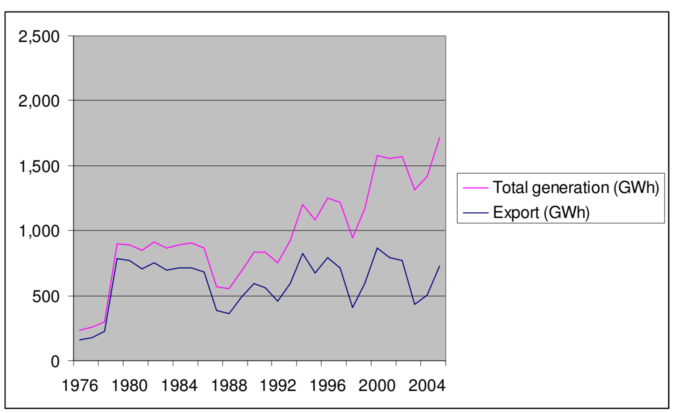

Figure 33 - Total electricity generation and export in Laos 1976-2005 (GoL, 2008)

This figures will change drastically once the Nam Theun 2 and other dams will be finished and exports will increase again. Most of additional electricity, even from dams where construction has not started yet, has already been sold. Memoranda of understanding have been signed with Thailand and Vietnam to deliver 3000 MW and 2000 MW respectively in 2010 (UNDP, 2006). These figures should progressively be increased to 7000 MW for Thailand and 3000 MW for Vietnam in

2020 (Vientiane Times, 10-01-2008). China and Cambodia are also expected to sign for the import of electricity from Laos in the near future. The import of electricity, which is currently necessary because the national grid is split up in four separate parts, will gradually be reduced and is expected to end in 2009 (UNDP, 2006). A small part, 10% of all electricity generated by hydropower projects, will have to be made available for domestic use, as decided by the government. All in all, these hydropower exports are expected to bring substantial benefits to the macro-economic situation of Laos over a long period of time, although there are some potential negative macro-economic effects as well, such as "fiscal indiscipline, poor debt management, 'Dutch disease' and other currency risks" (UNDP, 2006).

Expansion of the national grid

The abundant availability of cheap electricity from hydropower does not mean that electrification of the country itself is complete or nearly complete. According to the official statistics, only 43,1 % of the villages and 48,3% of the households in Laos were electrified in 2005.[12] This is still a remarkable increase from 10,6% and 18,9% of 1996 and a major step towards the ambitious goal of the government to ensure that 90% of the households has access to electricity in 2020 (MEM, 2005). The main method to reach this goal is to connect 80% of the households to the national grid and the remaining 10% through various off-grid electrification technologies.

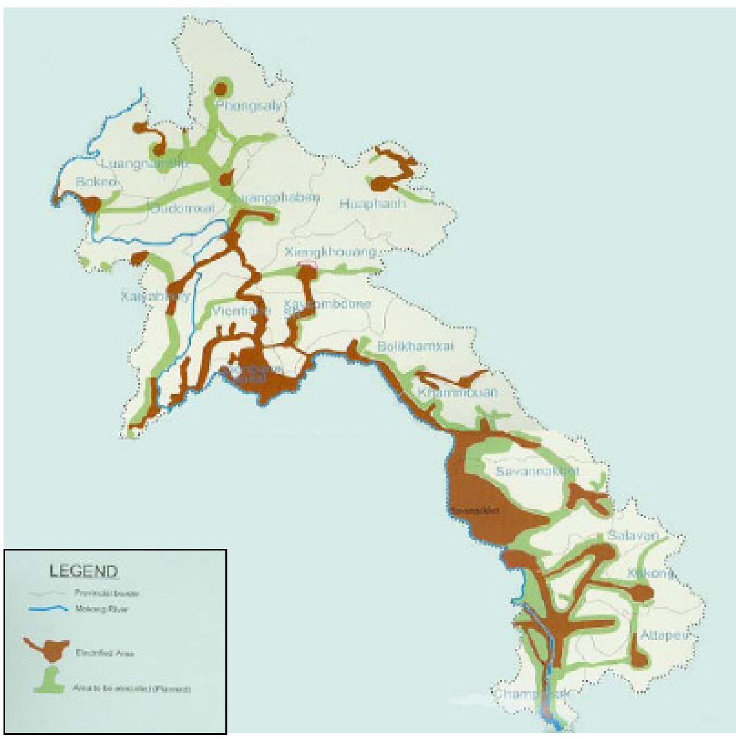

Figure 34 - Map of electrified areas (brown) and areas planned for electrification (green) in 2004 (EDL) in DGS (2006)

[12] The difference between the percentage of electrified villages and households is probably because the electrified villages probably have more households than non-electrified ones.

The jump in electrification rate in the last decade was made possible through major financial and institutional support from the ADB and the World Bank for the national electricity utility, Electricité du Lao (EdL). With their help, a big project to expand the national grid to the southern part of the country has been finished in 2004. Currently EdL is increasing its efforts to electrify the south while expanding the grid to the center and northern provinces as well (see Figure 34 for the status and plans of electrification in 2004). Electrifying the northern provinces will be more difficult, because of the rugged terrain and smaller population density in these areas. These factors are expected to slow down the pace of grid expansion and will render it less economically viable (World Bank, 2006).

Grid expansion to remote areas does not have to be the most favorable option to electrify rural areas. A first reason are the high costs involved in grid expansion and losses of electricity transport over longer distances. Graecen (2004), for example, shows that the provision of electricity using village micro-hydro systems are 26-47% cheaper compared to the national grid in remote areas for Thailand. Nevertheless, in many cases grid expansion has taken place, mainly due to political reasons in Thailand. Moreover, grid expansion does not necessarily mean that all people are able and willing to pay for electricity. This problem has been signaled in the reports of UNDP (2006) and Maunsell (2004). These reports do not quote any numbers, although the Maunsell report mentions that “not all households are connecting to the Main Grid when it is extended to new villages. If this rate of uptake continues, then national household connection rates may be constrained to around 60%” (p. 56). Besides grid expansion using electricity from large hydropower dams, there are several smaller alternatives.

Challenges of rural electrification

There are a lot of problems and challenges related to the all the electricity production technologies smaller than the 1 MW. In many off-grid areas in Laos, smaller locally generated electricity generation, using micro-hydropower or diesel, can be found (1 kW to 1 MW). This electricity is distributed through isolated or mini-grids, typically in and around provincial and district towns. The systems are owned either by the national utility, EdL, or by the provincial or district authorities. The EdL systems usually designed according to the same standards of the national grid, whereas those owned by the province or district level generally have lower standards (Maunsell, 2004, p. 49).

Judging from the available numbers, the current status of many of the smaller systems (<100 kW) is not very positive. shows the official statistics of the Ministry of Energy and Mines and the functioning of different categories of electricity production available. From this table, it can be concluded that mostly hydropower plants with lower output tend to be malfunctioning or even broken down, compared to the ‘small to large’ category for example. Especially in the category of systems from 1 to 100 kW 70% of the systems is damaged or has stopped working. A survey of eight of these micro-hydropower systems in Luang Prabang and Xieng Kouang province in 2000 indicates that the causes of malfunctioning are both technical and social. All of the systems were built by Chinese, Vietnamese or Japanese technicians using materials from these countries. These materials were sometimes outdated at the time of construction or wrongly assembled in the first place. Furthermore, there were many instances of bad maintenance and lack of spare parts available. Besides these technical issues, there was a lack of technicians, proper management and participation from the villagers as well (PADETC, 2001). This study gives some clues of the challenges of maintaining small rural electrification technologies.

Table 8 – Damaged hydropower and diesel generators (MEM, 2005)

Type	*Size*	*No. working*	*Capacity (kW)*	*No. damaged or stopped working (and %)*	*Capacity damaged or stopped working (kW and %)*
Small to large hydro	>1 MW	10	668,748	-	
Mini hydro	100 kW – 1 MW	6	951	3 (33%)	1,980 (68%)
Micro hydro	1 kW – 100 kW	9	454	21 (70%)	723 (61%)
Diesel generator	<1 MW	8	860	39 (83%)	7,953 (90%)
PV solar	<10 kW	194 (villages)	297	5 (3%)	2 (1%)
Total		227	671,310	68	10,658

Village and household electrification technologies

The remaining types of systems that generate electricity for people in Laos is much harder to trace in the official statistics and overviews of rural electrification. Some examples are car batteries, diesel generators, pico-hydropower units and solar panels. Car batteries are widely used throughout Laos for light and small entertainment such as television and CD players. Villagers can have their batteries charged at small commercial shops at the end of the national grid or at private shops with a diesel generator. Some people also use a diesel generator for personal electricity generation, but this is quite expensive and therefore not widespread. Solar home systems are generally too expensive for people in rural areas to purchase directly, but are leased and rented out by VOPS, a joint World Bank/GoL initiative and Sunlabob, a private renewable energy company respectively. Together, this amounts to an estimated number of around 6000 to 7000 systems at the beginning of 2008 in the whole of Laos (VOPS, 2008; interview 57). Finally, pico-hydropower systems usually generate less than 1 kW of electricity and are, just like car batteries and diesel generators, used on a purely commercial basis (without government or donor intervention) throughout the country but especially in the north. The remainder of this report will discuss the use and distribution of pico-hydro units in detail. As mentioned before, there are hardly any good statistics on the use of these small-scale household technologies. The number of PV solar systems mentioned in for example, does not include the systems of Sunlabob. As (p. 43) shows, pico-hydropower is considered a separate category of electricity production but there are no figures known by the Ministry of Energy and Mines. Car batteries and personal diesel generators do not appear in the official statistics and overview either, although they provide electricity for people not connected to the national grid. The inclusion of these technologies would seriously alter the existing statistics. For example, the report of Maunsell (2004) states that, if car batteries were seen as electrification, the rate of electrification in Savannakhet was close to 100% before the national grid arrived (p. 56). The report itself does not argue for the inclusion of car batteries in the statistics, but they do for pico-hydropower, albeit only if the systems are equipped with a controller (p. 65).

Electricity production is very important for Laos to be used for export, but rural electrification is still a big challenge. Geographical, demographical as well as (historical) political reasons underpin the current electrification strategies and difficulties. From the data about electricity production used can be concluded that the smaller off-grid electricity production systems get, the more difficult successful implementation of these systems becomes. Moreover, the general availability and accuracy of the data available decreases as the systems become smaller. Indeed, most of the technologies on household level do not appear at all in the statistics, because they are privately owned and the government lacks the capacity to collect this information. This raises the question what should be considered 'electrification', what should not and what the criteria are. Because of this lack of data, the only way to understand how technologies such as pico-hydropower are currently being used, where they come from and what their functions are in terms of electrification is to do fieldwork in the off-grid areas.

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Annex II: Methodology and field work areas

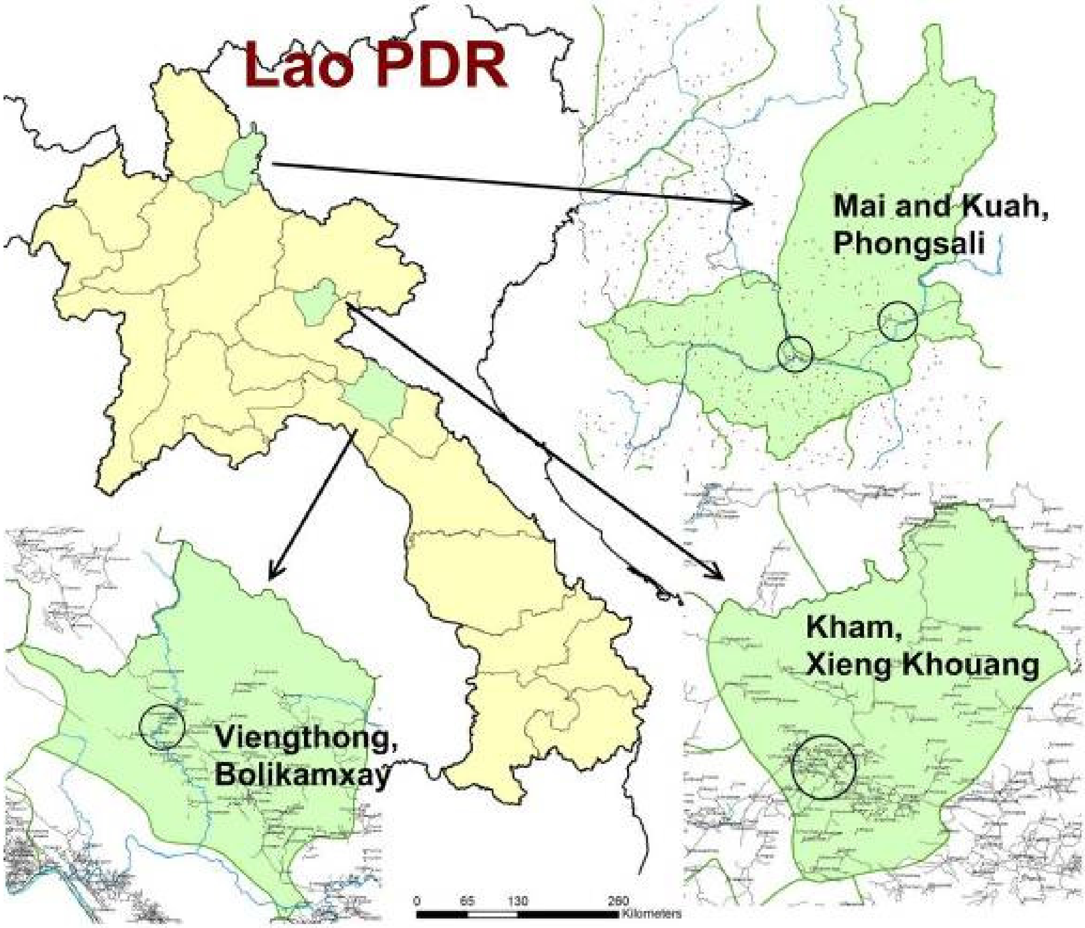

Figure 35 - Map of Laos with highlight on the three fieldwork areas

Methodology

This report is mainly based on empirical information collected during field trips. The three field trips took about one week each, preceded by some preparation time and followed by some time to process the data collected. The last three months of the report consisted of data analysis and writing.

Three field trips provided the basis to answering the first research questions. These were designed to get a complete picture of the use of pico-hydropower in three target areas of Laos, described in the first chapter. Several methods and techniques were used in order to achieve this. First, to get an understanding of the living conditions in the villages, general information was collected by doing interviews with the (deputy) village leader using a standardized questionnaire. This questionnaire contained both open and closed questions and was used in all three target areas. After each field trip, the questionnaire was reviewed and adapted to incorporate new insights and to improve the data collection. Information from the interview was complemented by observations and pictures made during a walk through every village and its sites with pico-hydropower.

Information about the *hardware*, the different types and working of pico-hydropower units, was collected by observation, interviews and secondary literature. Interviews with stakeholders in rural electrification provided a basic level of knowledge about the pico-hydropower units in Laos and two reports on pico-hydropower in Vietnam, the Philippines and Ecuador, were used as well (Entec, 2000; ESMAP, 2005). Observation in the field yielded more in-depth technographic knowledge about the type and use of pico-hydro units in the field work areas.

To gain insight in the *market* and distribution mechanisms of pico-hydropower units, interviews, observation and secondary literature were the methods used. Interviews were carried out with a total of 15 shop owners in the three field work areas to get information on the prices, origin, type of buyers and market developments. Walking through and making observations at these markets also provided useful information. The reports of Entec (2000) and ESMAP (2005) were used to put this data in perspective.

To answer questions about the *users* and use of pico-hydropower in the villages, interviews, observation and taking pictures were the methods used. Semi-structured focus group interviews were conducted in three villages in the first field work area, Viengthong district. In order to gain more personal information, semi-structured individual interviews were carried out in Kham district, the second field work area. In the last target area, Mai and Kuah district, individual interviews with more structure were conducted and some questions about pico-hydro were incorporated in the interview with the village leader. Thus, the methods were adapted to the progressing knowledge and experience during the research.

Overview field work areas

Fieldwork has been carried out to describe the hardware, use and market of pico-hydropower in different areas of Laos. Three different areas not connected to the national grid were selected, in the middle and northern part of Laos (see Figure 35). The main selection criteria were the different geographical features: the incidence of hills and mountain and the associated run of river. This has found to greatly influence the way pico-hydropower is installed and used. The first villages, in Viengthong district, are along a big river which is relatively flat. The second set of villages, in Kham district, represents a more hilly landscape with smaller rivers. The villages in Mai and Kuah district, the last group, are situated in a mountainous area, with many small streams. An additional reason to select different areas in the center and north of Laos was to account for differences between provinces and the diversity of ethnic groups in the country. These differences were found to be at best of minor importance related to the differences found in geographical features. The characteristics of each of the field work areas will be described in the remainder of the chapter.

Viengthong district, Bolikamxay province

The first fieldwork area is Viengthong in Bolikamxay province, which can be found in the middle of the country, bordering Vietnam on the east and Thailand on the west. Provinces connected are Khammouan in the south and Xieng Khouang, Vientiane province and Vientiane prefecture in the north. The area of the province is 14,863 km^2 and the population density is around 16 persons/km^2. The total number of people living in the province is 233,000. In terms of rice production, lowland seasonal wet rice production is the main mode of production (32,000 ha), followed by upland and irrigated rice lands (both around 3000 ha). Besides rice, people in Bolikamxay also grow maize, roots and sugarcane and keep livestock (NSC, 2006).

The area that is included in this research is situated in Viengtong district, one of the 47 poorest districts in the country.[13] The district was selected for research, because of the location of the villages along a big river (Nam Mouan) and because of its relatively low altitude. These characteristics influence the way pico-hydropower is being used. The choice for the specific villages was made after consultation with WWF, who carries out a project focused on fisheries in the area. Rough data with village characteristics gathered using the Participatory Rural Appraisal (PRA) methodology were therefore already available (WWF, 2007).

Fieldwork in the district was carried out in Mouang Muan, Thadeua, and Phiengton village. These villages were selected on the presence of pico-hydropower and because they will be affected by the Nam Theun I hydropower dam. All three of these are situated along the Nam Mouan river, a tributary of the Mekong. The main livelihood activities of these villages are lowland and upland rice cultivation, growing fruit and vegetables and animal husbandry. Some secondary livelihood activities are catching fish, collecting non-timber forest products (NTFPs) and hunting (WWF, 2007). In 2014 the landscape in Viengthong district will dramatically change, because by then the Nam Theun I dam will be finished. The basin of this 523 MW dam will fill up the valley of the Nam Mouan river, thereby forcing the villages situated at this river to be relocated (see . Lak Xao, a town close to the border of Vietnam, was also visited to collect information about the distribution and markets of pico-hydro in Bolikamxay.

Figure 36 - Area affected by the Nam Theun 1 dam, Bolikamxay (Norplan/EcoLao, 2007)

13 In the National Growth and Poverty Eradication Strategy (NGPES), the Government of Laos has selected 47 poorest and 25 poor districts on the basis of five criteria (GoL, 2003)

Kham district, Xieng Khouang province

The second area for fieldwork is Kham district, Xieng Khouang province and lies in the Northeast of the Lao PDR, bordering Vietnam on the east and Bolikamxay, Vientiane, Luang Prabang and Huaphan provinces surrounding it. The provincial area is 16,358 km^2 and the population is 246,153, (15 person/km^2). The type of rice production in the province is mainly lowland seasonal rice (19,000 ha) and there is also a substantial amount of upland rice production (9,000 ha). However, there are almost no irrigated rice paddies. Maize is becoming a very important crop in the province (about 10,000 ha), but people also grow vegetables, peanuts and soybeans. People in Xieng Khouang keep livestock as well: buffalos, cows, pigs and poultry being the most important ones. The province is situated on a elevated plateau, which makes the climate considerably cooler than that of the Mekong valley. The whole province is hilly, but the landscape becomes mountainous towards the border to Vietnam (NSC, 2006).

Kham district in Xieng Khouang province was chosen because its landscape is more hilly than Viengthong and thus represents quite different geographical conditions. Instead of one big river, there are several small and big streams. An additional reason to choose this district is the presence of Tha village, where a pico-hydropower project has been carried out.

The district is situated in the center-North of the province and the two villages researched, Khaivieng and Moh village, are along main road no. 6 leading towards Vietnam. Besides the use of pico-hydro, the villages were selected because of interesting characteristics: an irrigation project and resettlement in Moh village and merger of two villages to one in Khaivieng village.

Most of the people living in these villages are ethnic Lao (Lao Loum). The most important livelihood activities are growing rice, vegetables and fruit (e.g. garlic and bananas) for subsistence and to sell at the market. In the last two years, red maize, that is processed into animal fodder in Vietnam, has become a very important additional income generating activity. People also keep livestock, but only small numbers of animals are sold at the market. An important development is the construction of grid electricity on the main road in Kham district. It is expected that people will have access to this electricity in the course of 2008. To collect information about trade in and markets for pico-hydro, the provincial capital of Xieng Khouang, Phonesavan, and the district capital of Kham, Chomthong, were included in the field trips as well.

Mai and Kuah district, Phongsali province

Mai and Kuah district in Phongsali province are the third fieldwork area and situated in the north of Laos, bordering Vietnam on the east and China on the west. The total area of the province is 16,270 km^2 and number of people is 168,000, making it one of the least populated provinces in Laos (10 person/km^2). The province is situated at high altitude and is very mountainous. Rice production is the main livelihood activity and the province has more upland rice than seasonal (lowland) rice fields, around 8000 ha versus 6000 ha respectively. In addition, people in Phongsali grow maize, peanut, soybean, mungbean and sugarcane. It is also one of the only places in Laos where tea is grown. (NSC, 2006)

The districts that were visited for this research are Mai and Kuah, both situated in the southern part of the province and included in the 25 poor districts of Laos (see footnote on p. 52). In comparison to the two other areas, Mai and Kuah district are the most mountainous and there are many smaller and larger water resources available in this area. Other reasons for selecting these areas are the high numbers of ethnic minorities and the close proximity to Vietnam and China, where the pico-hydropower units are made.

Mai district has a long border with Vietnam on the east side of the district and has an international border crossing since 2007. Muang Kuah, on the other hand, is an important junction for traffic coming from Vientiane or Luang Prabang and heading to China or Vietnam. The villages included in this research are Sop Nhao, Sop Poun, Huay Wang Khao and Sen Art in Mai district and Huay Phae Ou and Taang Kok in Kuah district. These villages in Mai district were selected, because they are relatively typical villages for the area that are still relatively easy to reach by road. To contrast this, the villages in Kuah district were selected, because they could only be reached by boat.

For their livelihoods, the villages visited in Mai district are mainly dependent on lowland rice, whereas those visited in Kuah district only produce upland rice. People keep only a small number of livestock, as a result of many outbreaks of animal diseases in the past few years. An important influence on Phongsali is a contract of the provincial government with a Chinese rubber producer from two years ago. An effect of this is that almost all of the villages in the province had to start growing rubber trees two years ago. Information about shops and the market for pico-hydro turbines was collected at the district capitals of Mai and Kuah.

The fieldwork areas, selection criteria, villages, market and type of data collected are summarized in .

Table 9 – Overview of target areas included in this research

Province	***Viengthong, Bolikamxay province***	***Kham, Xieng Khouang province***	***Mai and Kuah, Phongsali province***
Selection criteria	• Relatively flat • Big river	• Hilly • Small streams	• Mountainous • Streams and rivers
Villages	• Muan Muang • Piengton • Thadeua	• Khaivieng • Moh	• Sop Nhao • Sop Poun • Huay Wang Khao • Sen Art • Huay Phae Ou • Taang Kok
Market	• Lak Xao (3 interviews)	• Phonsavan (10) • Chomthong (2)	• District capital Mai • District capital Kuah
Type of data	• Interview with village leader • Focus group interviews	• Interview with village leader • Individual interviews	• Interview with village leader • Individual interviews

Annex III: Technography

Technography describes the use and networks of technology in a broad sense. Technography is defined by Richards (2006) as the analysis of skilled making based on detailed contextual description, including technical details, and the pursuit of mechanisms of transformation of technologies. It is an approach that builds on fundamental proposition of science and technologies studies that technologies are not a linear outcome of scientific endeavor, but that they reflect social relationships, different interests and power relations. Besides rejecting this technological determinism, technography also recognizes the pitfalls of the radical social constructivism in which case the only conclusions one can draw are that the world is intrinsically complex and that values cannot be compared or judged. Therefore, technography recognizes the social aspects of technology while also looking for 'real' structures and powers that influence the development and transformation of the technology. This shows that the technography approach is heavily indebted to Critical Realism for its ontological position.

The recognition that technology is transformed by structures and powers, makes it suitable to be studied as a network. Studying technology as a network extends the definition of technology beyond the physical hardware as it is used in day-to-day vocabulary. Such a network consists of hardware, people, physical features, organizations and any other relevant elements. A way of studying technologies as networks of different 'actors' is the Actor-Network Theory (ANT). The actors in ANT are all treated equal, which implies that no differences are being made between human and non-human actors. Instead, ANT studies technologies as hybrid socio-technical systems, thereby crossing the boundaries between the natural and social world (Law, 1992; Law and Callon, 1992; Latour, 1993). Similarly, understanding technology in this way should value knowledge and expertise of users as much as that of scientists, because they interact and shape technology on a daily basis (Richards, 2001; Collins and Evans, 2002).

ANT will be used as a descriptive tool in the analytical framework, although advocates of the theory usually use it in more explanatory ways. The ANT is integrated in the framework to study pico-hydropower as a network consisting of interrelated social and natural actors, such as traders, cables, users and rivers. By using a network approach, it is shown that pico-hydropower relies on several related actors, markets, water, light bulbs, to finally get to light as an 'outcome' of the system. Moreover, the proposition of hybrid networks shows how people and objects have different functions, but that one cannot value one actor over the other. For example, the material that is necessary is as important as the person that construct the pico-hydro unit.

Technography as it is used in this report, is a highly empirical approach to the study of technology to describe the hardware, use and markets of pico-hydropower in Laos using the actor-network theory as a tool. Since there is hardly any information available on pico-hydropower, this is an important and necessary first step. However, the objective of this report is to identify the mechanisms that explain the non-support for pico-hydropower by national actors. Therefore, the technography approach must be supplemented with an approach to analyze technology in its broader political environment.

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