The critical factors for success of stand alone energy schemes

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Access to electricity in developing countries

Electricity is recognised as an important element in social and economic development, by contributing to economic growth and/or improving a range of basic welfare services, such as drinking water, food, health and education. “The message of ETW (Energy for Tomorrow’s World) is to remember that health, water, food, education, and many other key aspects of welfare cannot be improved unless modern energy becomes available to all”[1]. In fact it argues about the key role of energy to provide other elemental services in development world, hence the priority of its promotion. The World Bank states: “Likewise poverty in developing countries cannot be reduced without greater use of modern forms of energy”[2]. Mariginac and Scheneider, argue that: “The degree of development of a society can be expressed in terms of increasing ability to meet a certain number of fundamental needs; They can be basic-food, housing, clothing, or more elaborated ones like education, culture, exercise of civil rights, quality of the natural environment, leisure, etc. But most of them require energy in varying degrees, thus making the availability of energy an absolute pre-requisite to economic and social development” [3].

However the access to electricity is one of the most difficult tasks that governments and development agencies confront, especially in developing countries. It has been estimated that nearly one third of the world’s population had no access to electricity by the end of the 20th century, the great majority of them living in developing countries[1,4]. Figures in the literature show that despite the efforts of governments to increase the access to electricity in developing countries, raising the electricity coefficients, the total number of rural inhabitants with no access to such a basic service remains very high; According to world Bank information in 1970 there were about 1850 million inhabitants in developing countries without access to electricity and by year 1990 the number was about 2 million[5].

Among other issues the most important related to rural electrification worldwide are:

a) The uneven access to electricity within continents, and regions[1]; and similarly within countries in each region, and within zones and areas in each country. According to the World Bank[6], while the Sub-Saharan countries had only 8% rural electrification coefficient by 1990, the south East Asian countries had an average of 45%, and the Latin American and Caribbean countries had average of 40%, by the same year.
b) One estimate of the total energy investment needed in Africa to 2010 was US$ 110 billion, which is approximately the 1992 cost of the German reunification, or the total flow of all aid monies to the Third World in 1990[7].
c) Despite the apparent fast growth of rural electrification coefficient from 18% to 33% in that period and the apparently slow growth of the urban electrification from 52% to 76%, the actual figures show that while urban population increased 3.5 times from 1970 to 1990, rural population increased only 2.5 times in the same period[5].

Energy needs and consumption in developing countries

According to literature, energy consumption is an important national development indicator, the higher the average energy consumption per capita is, generally the more developed the country is. 1997 statistics[6] shows for example, that while the average per capita electricity consumption in the South Asian countries was only 324 kWh/year, the average electricity consumption in the higher income countries was 8238 kWh/year (25 times higher), such a difference is much higher when referred to specific cases; in Canada 15,829 kWh, Norway 23,499 kWh; while in developing countries: in Cameroon 181 kWh, Guatemala 404 kWh, Haiti 42 kWh, China 714 kWh, Peru 607 kWh.

However the figures also confirm that energy consumption and development are not proportional. Such non-linearity can be attributed to the fact that energy is used not only to generate income and development, but it is used for a variety of applications (industry, transport, heating, cooling, comfort, recreation etc.), it is also used in a wide variety of weathers and environmental conditions, with different technologies.

Besides the small amounts of energy (per capita) required, another important characteristic of rural electrification demand is its dispersion of consumers, because most rural population live in small dispersed villages, communities or settlements. This fact makes access to commercial energy services difficult and expensive, especially electricity from national grids.

Rural energy options

Small stand alone energy schemes have been suggested as appropriate options to meet rural energy needs, especially those based on renewable energy schemes, solar photovoltaic systems (PV), small wind electricity generators, small hydro, biomass and small diesel sets. Such options are appropriate for small and decentralised energy generation in terms of: low generation costs, use of local resources, feasibility of sizing plants according to needs, feasibility of local management and participation of people in the selection of the energy options.

Critical factors for successful implementation of rural energy systems

The main hypothesis of this paper is that there are Critical Factors (CF), that influence the success or failure of isolated stand alone energy schemes in rural areas; these CF may be related to social, economical, technological, managerial, institutional and legal aspects. The identification of those factors worth consideration required a literature review of previous field research studies related to isolated stand alone energy systems installed within rural electrification projects and programmes, renewable energies and/or rural energy, pilot projects. The identification of the critical factors and their ranking in terms of the relative influence of each CF for the case of Peru was investigated through field research work.

There is a vast literature on rural electrification, rural energy, renewable energies, and related subjects; especially related to technical aspects, like performance, design construction and piloting different technology options, also there are a significant number of grid extension impact evaluations. This study included projects on stand-alone energy systems for rural electrification, both at national[9,10] and international[11] level and some relevant studies on rural electrification programmes with grid extension; especially impact studies of large programmes. Single system projects were excluded because they generally describe particular cases for particular villages that may not be replicable; purely technological papers were also excluded.

The outcome of the literature research was that there are thirteen possible Critical Factors, which had been recognised in the different studies; these are shown in the table bellow.

Table 1. Possible Critical Factors

Social	Financial	Technological	Managerial
• Benefits from electricity on household • No political interference • Community participation	• Low connection cost • Effective bill collection • Capacity to pay • Cost of energy	• Local capacity • Load factor/end uses • Technical support • Source of energy	• Ownership • Management

Field research, methodology and sampling

The field research was made in Peru, a country with one of the lowest rural electrification coefficients of Latin America - 32%, with great dispersion on the rural population and complicated geographical patterns. Peru also has a large disparity of electrification coverage between regions, Lima has 95% electrification while others like Cajamarca and Hunuco have about 30%.

In Peru during the 1990s, structural reform of the sector allowed investment and growth of the supply for the urban areas, for the commercial and industrial sectors. These reforms failed to develop a rural electrification strategy to cope with accelerating the rural electrification process, which had significant investment in the 1990s at the time of the reforms and then a complete stagnation afterwards.

A survey sample was designed considering the different conditions that affect the access of energy to isolated villages, location, technologies used, size of the systems, geographical conditions, ownership and management of the schemes and others. Two main strata by technology were chosen, small hydro schemes and diesel sets.

Survey sample

The survey sample was made in two steps, first a village sample survey (Table 2) and then in each village it was again necessary to get a sample to do the actual interviews.

A *stratified sampling is a method for obtaining a greater degree of representativeness and thus decreasing the probable sampling error*. Taking into consideration these criteria, the village sampling was done as follows:

- Organise the two technological strata (diesel sets and hydro schemes) and sample each strata independently.

- The technology strata was ordered according to the poverty index of the correspondent village, starting at the poorest level, using the poverty map[8], this was to include villages with different poverty degree.
- The ordering of the villages in such a way allowed getting a mix of government and municipal administration.

The survey sample was made of 14 schemes, 7 of them hydro schemes (H) and the other 7 diesel sets (D), located in the Andes and Upper Jungle regions, with outputs ranging between 20 and 200 kW, and with different ownership and management.

Table 2. Main features of the sample surveyed

Village	Poverty index	Power (kW)	Scheme age	Owner	No of interviewees	Number of Users
Maria(H)	0.0552	20	10	Community	28	149
Shitariyacu(H)	0.0596	120	5	Municipality	40	450
Mayorarca(H)	0.0622	40	9	Community	15	60
Chaviña(H)	0.0728	90	26	Government	25	346
Santa Catalina(H)	0.0756	90	7	Municipality	25	99
Longuita(H)	0.0785	40	7	Municipality	22	210
Las Juntas(H)	0.0866	25	5	Community	12	55
San Martin(D)	0.0438	50	6	Private	16	120
San Roque(D)	0.0597	60	6	Community	24	250
Limabamba(D)	0.0598	50	8	Municipality	21	60
Totora(D)	0.0711	50	7	Municipality	18	60
Tambo Quemado(D)	0.0728	40	5	Government	21	88
La Coipa(D)	0.0782	90	20	Municipality	25	250
Mazocruz(D)	0.0963	120	7	Municipality	45	350

A second level of sampling was made to get the population to be interviewed. Four groups of stakeholders were identified and household electricity users, business people, operators and administrators of the systems and leaders and local authorities. The actual sample of interviewees was made of about 10% of families living in each village, with a total of 337 in the 14 villages.

The collected information from the field is mainly of two types: a) information from the villagers regarding technical performance, administrative activities, energy generation and consumption, operation and maintenance activities, costs and others related to the functioning of the scheme; b) information about opinions of the users with regard to the benefits of electricity, behaviour of members of the villages regarding the different activities to run the schemes, capacity and willingness to pay. Such information was gathered through interviews and mostly closed questions to the different stakeholders.

Analysis of social factors

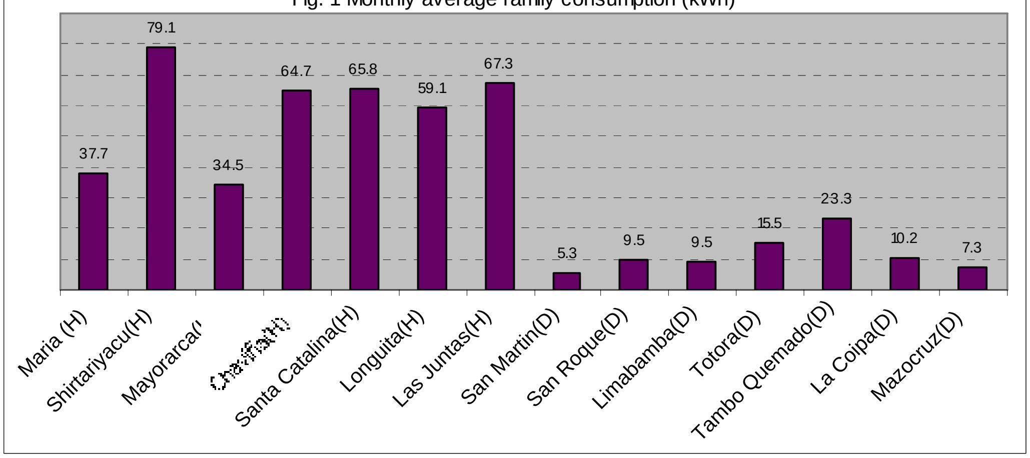
Regarding benefits of electricity, the study reveals that lighting; radio and TV are the most popular electricity use by far. In all villages, 100% of the interviewees use electricity for lighting; an average of 93.5% uses it to play small radios and 75% to play TVs. Looking at the technologies separately it is found that the percentages vary only marginally with technology (about 1% difference between diesel and hydro). The growth of the number of users depends very much on the location; for example, villages in the Upper Jungle have grown faster than those in the Andes.

The fourth most popular use of electricity is to play VHS systems. VHS are generally used for short periods of time (1 to 2 hours), which is suitable even in villages with few hours electricity service; nevertheless, those villages with hydro schemes have more VHS than those villages with diesel sets.

A total of 75 electrical appliances were found within the whole survey sample, 64 of them in villages with hydro schemes and the remaining 11 in villages with diesel sets. The most important reason for such disparity in the number of appliances is number of hours of electricity service per day.

The energy consumption per family is very different in villages with hydro schemes (monthly average of 58.3 kWh/family) compared to those in villages with diesel sets (monthly average of 10.1 kWh/family). See Fig. 1. It is estimated that in villages with hydro schemes about 15% of the total energy consumption is for public lighting; for diesel sets it is assumed that they have approximately the same consumption for public lighting, except for San Martin where, they have only few public lights.

Fig. 1 Monthly average family consumption (kWh)



Among hydro schemes, the two with the lowest average energy consumption are those community managed, Maria and Mayorarca, however Las Juntas (also community managed) has a much higher consumption than the previous cases. The large difference on consumption between hydro schemes and diesel sets is mainly attributed to the few hours of operation of the diesel sets.

The great majority of interviewees, in both villages with hydro schemes and with diesel sets consider that better conditions for children to study, access to more and better information, and security are the three most important benefits; other benefits apply for villages with small hydro like paying less for energy relative to non-electric options, food preservation and income generation but these are less important.

The study reveals that there is frequent political interference in the electricity services in isolated rural villages. Such interferences come mainly as promises from politicians who look for positions in the national (Members of Parliament) or local (Mayors) organisations; to a lesser extent it comes from politicians already in power, who want to maintain their popularity to be re-elected. Out of the 14 cases studies, 12 reported that they have been approached by politicians to offer improvements or changes to the systems. The most common offer by far is the connection to the grid. The reasons for the cases with no interference appear to be different. In Mayorarca the community enjoys the strong local leadership (representatives in the National Association of Peasants); and in Chaviña it is a government owned scheme, managed by the Regional Concessionaire.

Most villagers and local leaders recognise that politicians are looking to gain votes, but do not deliver anything when they get into power, however they distract the attention of people and sometimes create confrontation between members of the community regarding critical issues such as tariffs or penalties for non-payment.

Community participation

The study reveals that, for hydro schemes, those installed by NGOs have had more participation in the decision making for the installation. Church and municipalities had also good community participation, particularly where the management had been handed over to communities afterwards; while systems installed by the government have no community participation (were installed under a top-down approach). There has been little financial contribution from the community, except for Las Juntas.

As for villages with diesel sets, it was found that there is much less participation in both decision-making and labour, and no financial contribution. This is because diesel sets require much less non-qualified labour, but also because most of the systems are implemented under the top-down approach.

In all villages with hydro schemes there is clearly good community participation in maintenance activities, except for Shitariyacu (where almost 40% do not take part in such activities); while in villages with diesel sets there is little community participation in maintenance.

In villages with hydro, the participation of the users is mainly in the maintenance of civil works, they almost never take part in the maintenance of the equipment (the users take part in activities that do not require qualified skills); which explains that the little or non-participation of the users in the maintenance of diesel may not only be the lack of interest of the owners and managers but primarily the fact that diesel sets require skilled labour, which is lacking in rural areas.

In the villages with hydro schemes the willingness for more participation varies from 20% to 75% of the interviewees, while in all villages with diesel sets the percentage of people with willing to participate more is higher (above 80%). The most likely reason for such a difference is that, in villages with no participation at present, they would like to have some participation, while the opposite is true for those where there is participation.

The case of Las Juntas is exceptional, because there is a very good story of community participation, but when they were asked about their willingness for more participation, they all said that they have enough participation.

Analysis of financial factors

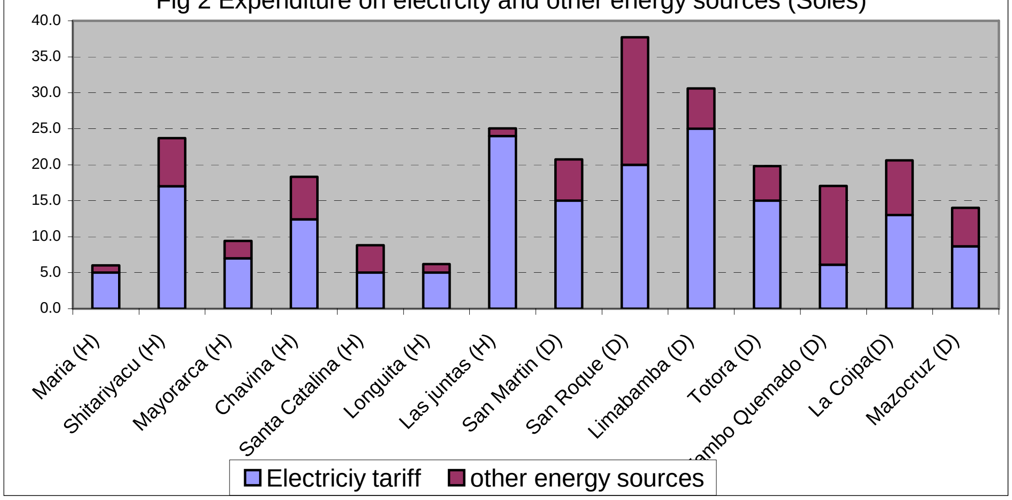
For domestic users, out of the 14 villages surveyed, in 12 the average connexion cost was very low, between 10 to 50 Soles (US$3.08 to 15.38); in the other 2 villages the connection cost had been much higher, in Las Juntas 100 Soles (US$ 30.77) and Chaviña 350 Soles (US$ 107.70). In Las Juntas, the leaders explained that the connection cost was that needed for the service connection from the low tension distribution lines to each home, while in Chaviña the connection cost was just informed by the utility. For business people the situation has been very similar as for domestic users.

It was also found that in 5 systems, 3 hydro (Shitariyacu, Chaviña and Mayorarca) and 2 diesel (San Roque and Mazocruz), the amount paid for connection to each family was different for each family. In Chaviña for example, the users were charged from as little as 10 Soles to as much as 510 Soles. Regarding opinion about the connection cost, the majority of those living in villages where they paid a low connection cost, said that it was OK, the exception being the case of Las Juntas, where despite the relatively high charge for connection, most said it was OK or even that it was cheap.

Cost of energy

As shown in Figure 2, the total monthly expenditure on energy ranges from 6.0 Soles (US$1.85) to 37.7 Soles (US$ 11.6), including electricity and other sources; while the expenditure on electricity only ranges from 5.0 Soles (US$ 1.54) to 24.0 Soles (US$ 7.38) and the range of expenditure on complementary sources of energy range from as little as 1.0 Soles (US$ 0.31) to as much as 17.7 Soles (US$ 5.20). The most common complementary sorts energy being wax candles, kerosene, dry batteries and exceptionally wet batteries, these complementary sources are only for lighting at home and/or for torches when they need to leave the village during the night.

Fig 2 Expenditure on electrcity and other energy sources (Soles)



Three types of tariffs were found: i) Two systems -one hydro scheme and one diesel set- use the government regulated tariff; ii) Two systems -one hydro scheme and one diesel set- use a metered tariff but not regulated, the hydro scheme is Community owned and the diesel set is Municipality owned; iii) Ten systems have flat tariffs. Table 3 shows the sort of tariff used in each village and the average monthly payments for electricity service.

Significant disparities have been found in many schemes (hydro and diesel) regarding tariffs. The highest average payment for electricity service among hydro schemes occurs in Las Juntas – with a descending block metered tariff, followed by Shitariyacu and in third place Chaviña; the other 4 hydro schemes have a very low flat tariff. None of the villages included in the survey sample has taken into consideration the poverty index to set the tariffs.

Similar disparities happen for diesel sets; the village with regulated tariff –Tambo Quemado – has the smallest monthly average of all the villages with diesel sets, the second smallest tariff is in Mazocruz (despite having a high metered tariff). The other five villages have different flat tariffs.

Table 3 Tariff structures and monthly average payments

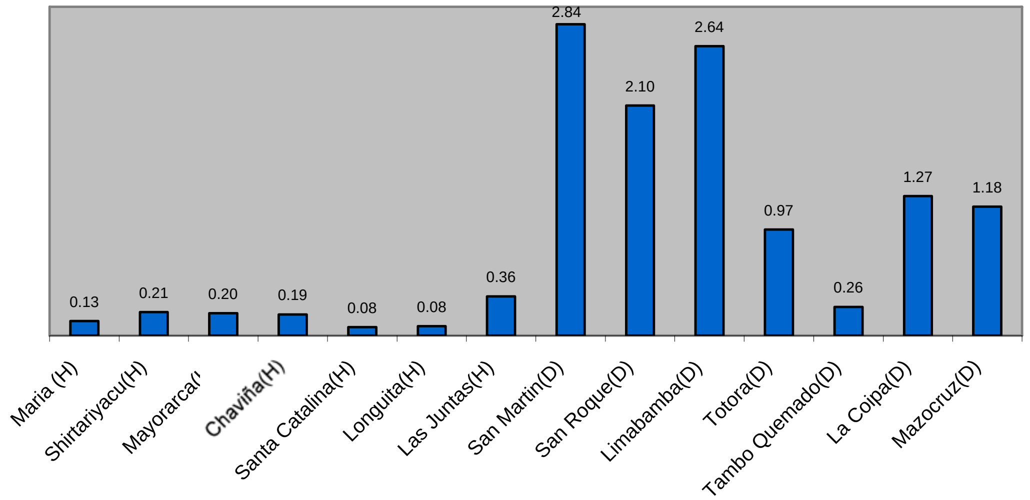
Village	Tariff	Amount (S/)
Maria(H)	Flat	5
Shitariyacu(H)	Flat	17
Mayorarca(H)	Flat	7
Chaviña(H)	Regulated*	12.4
Santa Catalina(H)	Flat	5
Longuita(H)	Flat	5
Las Juntas(H)	Metered not regulated (Descending blocks)***	24
San Martin(D)	Flat	15
San Roque(D)	Flat	20
Limabamba(D)	Flat	25
Totora (D)	Flat	15
Tambo Qemado(D)	Average (Regulated*)	6.1
La Coipa	Flat	15
Mazocruz(D)	Metered** (not regulated) 1.0 Soles per kWh	8.6

* Has a government regulated tariff, 0.52 Soles per kWh
** Charged according to consumption at a rate of 1.0 Soles per kWh
*** The first 20 kWh costs 0.52 S/kWh, from 20 to 60 kWh: 0.40 S/kWh, above 60kWh costs 0.10 S/kWh.

Figure 3 shows that families living in villages with diesel sets clearly pay a much higher amount per energy unit consumed; while the average cost for hydro schemes is 0.18 Soles per kWh (US$ 0.055), for diesel sets it is 1.61 Soles per kWh (0.49 US$); that is, families living in villages with diesel sets pay nine times the amount paid by those with hydro schemes.

In the villages with diesel sets, where electricity is metered, despite the apparently high unit energy cost, the average monthly cost of electricity per family is lower that that paid in villages with flat tariff rates, which suggests that flat tariffs in many cases are simple and cost effective from the management and income point of view.

Fig 3 Cost per kWh average (Soles)



Capacity to pay

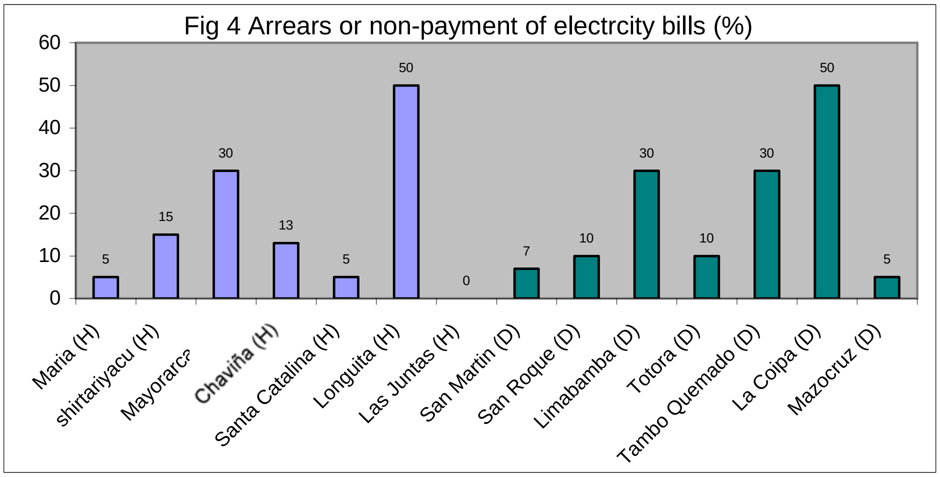
People living in villages with diesel sets clearly expend more in energy globally as shown in Figure 2. Those people in villages with diesel set pay much more for energy and for electricity than those in villages with hydro schemes. And although there are some significant payment arrears, the results reveal that these are not because consumers are unable to pay, but because there are no clear rules or penalties for non-payment.

Therefore the results suggest that, despite people spending a high proportion of their budget on energy and particularly in electricity, they are able to pay, or they prioritise this expense over other needs.

Effective bill collection

As shown in Figure 4 most of the systems have considerable payment arrears; however it is more frequent and with higher percentages for diesel sets than for hydro schemes. The results reveal that the size of the tariff does not influence on the arrears; for example, La Coipa has the lowest tariff among the diesel sets, however it has the highest arrears of all the systems, while San Martin has slightly higher tariff but has only 5% arrears; in Las Juntas despite having the highest average payment per family of all the systems, the arrears are negligible.

Among the reasons for arrears are: lack of money, poor quality of service, the relation between customer and administrator (community managed consumers generally feel that they have a better service), lack of rules to meet obligations. However in most cases there are families willing to pay more for a better service, which partly explains why hydro schemes have a better performance on bill collection.



Analysis of technical factors

To investigate local capacity, the two main issues were the staff employed to run the systems and their education and training. The study reveals that all the systems except for Tambo Quemado have operators, but only 5 have administrators; this fact shows the lower importance given to administration compared with operation of the electricity services in rural areas.

The level of education is low for all the systems. Out of a total of 15 operators running the systems, 5 have only elementary education; including one with incomplete elementary education the other 10 have at least some high school education. As a general trend the study reveals that administrators have better education than operators. In all systems there was some initial training for operators; however, considering that energy systems are new technologies for the villagers, the reported training periods were short and insufficient to cope with the full maintenance of the schemes.

In 12 out of the 14 villages surveyed the operators and/or administrators interviewed said that there is need for technical assistance; the other two are those owned by the government, where the management is in the hands of the regional utilities, who send trained technicians (from other schemes) to do regular checks. In only 3 out of the 12 villages needing technical assistance, interviewees said that it is easy to find technical assistance, in the other 9 cases it was reported to be either “difficult” or “very difficult” to obtain.

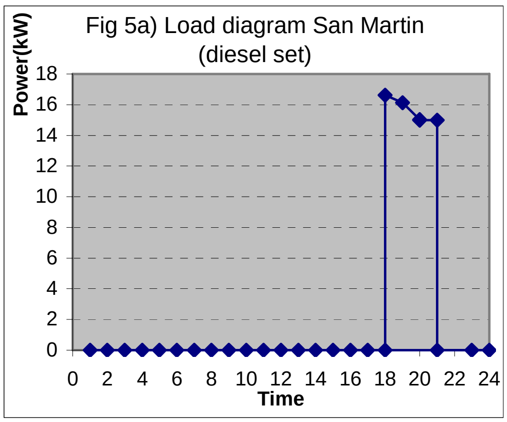
Reliability of supply and energy consumption

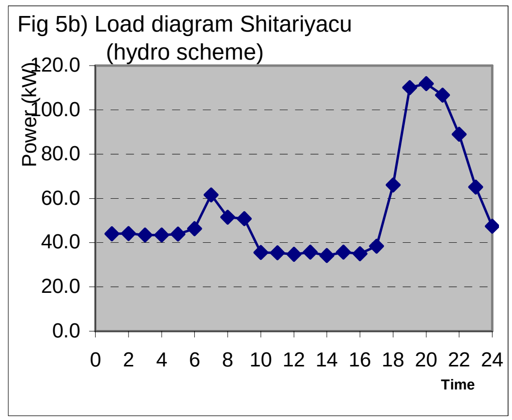
The number of down time days per year varies in a very wide range from as little as 3 days for the hydro scheme Las Juntas to as large as 206 days in the diesel set San Martin. Generally the hydro schemes have a more reliable supply than the diesel sets.

There are three main reasons for down time days, for both hydro and diesel sets, i.e. lack of fuel or water resources, lack of spare parts or experts and lack of money. Three hydro schemes recorded water shortfalls during the dry season, Shitariyacu, Maria and Longuita; this was partly as a result of poor scheme design. For diesel sets the most significant reason for down-time was the lack of fuel. Although for the case of the private managed diesel set (San Martin) the owner agreed to provide the service only 4 days per week due to lack of money to buy fuel. However, in part this was also a unilateral decision by the owner to ensure a good financial performance of his business.

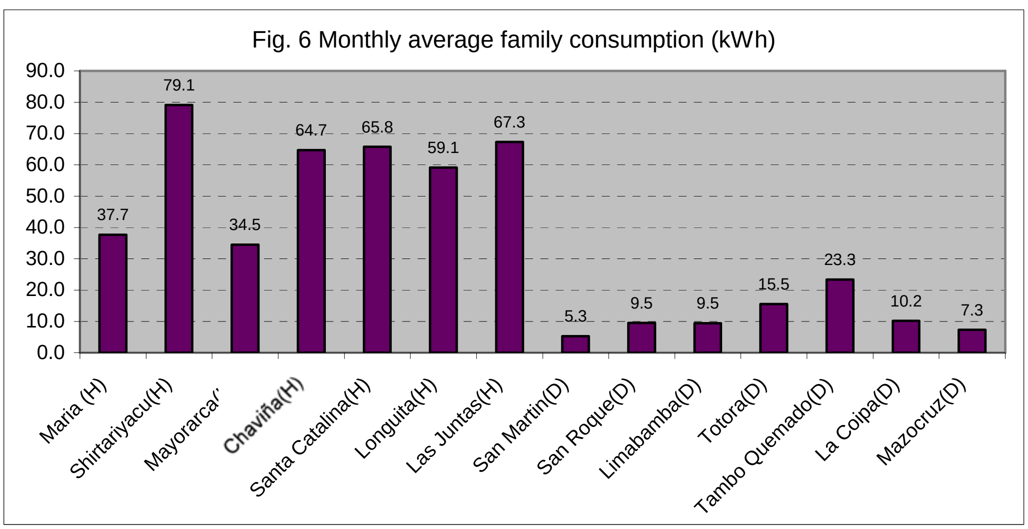
There is a large difference in energy consumption between villages with hydro schemes and villages with diesel sets, the most significant reason is that diesel sets provide energy very few hours per day varying 2 to 5 hours, meanwhile hydro schemes provide 24 hours electricity service, except for Mayorarca, where the community decided to run their hydro scheme for 12 hours per day.

The typical load diagrams for diesel sets have little variation during the few hours of operation, as examples see Figures 5a and 5b for San Martin and Shitariyacu respectively.





The energy consumption per family (based on total plant output) is much higher for hydro schemes than for diesel sets, as shown in Figure 6.



Diesel sets show a low family consumption for all cases, primarily due to the limited hours of service, which in turn is because of the cost of fuel; other factors are the unreliability of fuel supply and lack of experts or the lack of money to repair the systems quickly. For hydro schemes the lowest energy consumption happens for the community managed schemes (Mayorarca and Maria). The reasons are different in each case: in Mayorarca it is because the scheme runs only 12 hours per day. In Maria they have only 20 kW capacity with 159 consumers, which was solved by providing awareness to users showing how to use energy saving lamps and switch off unused lights and other appliances.

The source of energy clearly influences the use of energy. It was found that there are significant differences in tariffs, participation, use of energy, appliances, etc. Hydro schemes have more reliable energy during the year, and all but one have 24 hours of electricity a day. For diesel sets, the reliability of the fuel supply plays an important role in the electricity supply; those more isolated from the large commercial centres have less regular fuel supply.

Analysis of management factors

This study covers Government, Municipality, Community and Private ownership and management; Cooperative owned and managed systems were not considered because there are very few in the country.

Evidence from the literature review suggested that ownership is an important issue because many, if not all the decisions, such as: type of management, tariff structures, community participation, are influenced or decided by the owner. However ownership is a fixed parameter, which will rarely change with the time. This research study reveals that the ownership of most of the systems surveyed was decided before installation. However, in the case of San Roque the government decided to hand the property to the community after it was installed.

Those systems managed by the government are generally the largest ones. Although there is not a precise power size limit, hardly any government installed system below 50kW has been retained as government property.

The two government-managed systems (Chaviña and Tambo Quemado) included in this study show a good technical performance. Government owned systems are operated by regional utilities; the amount paid to perform that service is not in the public domain, but it is understood that small systems like Chaviña and Tambo Quemado are heavily subsidised by the government. However, in practice the utilities hire local villagers to perform the basic operation and administration activities.

Half of the surveyed systems are managed by municipalities, 3 hydro schemes and 4 diesel sets. All of these show problems of poor management, most of them from the lack of local capacity to perform good maintenance; all showed a high number of down time days per year. Municipalities appear to have difficulties to get spare parts or access to experts. In most large towns, it is possible to find almost all spare parts, so the main problem appears to be the lack of money or difficulties to take decisions to buy the parts, which is clearly a management issue.

Community managed systems tend to be weak technically. Among the hydro schemes, out of three, two (Mayorarca and Maria) show the highest down time per year due to the lack of experts and/or spare parts, which is mainly due to the poor information they get and their difficulties to keep records. However Las Juntas is exactly the opposite and shows the best performance of all cases. For diesel sets, the only system of the sample under community management – San Roque – shows the second largest down time days per year, due to similar reasons as for hydro schemes.

Las Juntas is the only community managed system which shows a totally different picture, an excellent performance in all the fields: good management of the systems, proper tariff scheme, people trained to operate and maintain the scheme, bank account, independence from political interference, own office, etc. The difference is clearly in the use of private management, where the owner –the community- hires a very small local company to operate the system and it pays for such work. This scheme was set up with the support of the NGO Practical Action. Internal rules and conditions were set up to govern the responsibilities of the various stakeholders.

San Martin is the only system under private ownership and management, where a villager invested his own money to implement electricity services for the village. San Martin shows different characteristics from all the other systems, it has a good financial performance but a very poor technical performance. It has many down time days and few operating hours each day so it supplies the lowest energy per family but the electricity price (per kWh) is the highest of the entire sample.

Management facilities and financial performance

Among the facilities considered necessary to perform the management activities are: tools and office. It was found that only 3 out of the 14 systems (two hydro and one diesel) have their own offices; another 3 (1 hydro and 2 diesel) share offices with other facilities; the other 8 systems just use the powerhouse as the office, although it is not necessarily recognised as such. None of the 14 systems have all the necessary sets of tools and instruments necessary to perform proper maintenance. Among the reasons for the lack of the necessary tools are: the lack of information about suppliers and the lack of money.

The financial performance is clearly better for hydro schemes than it is for diesel sets: 5 out of the 7 hydro schemes of the survey sample have positive net income. For diesel sets the financial performance was found to be the other way around: 5 out of the 7 cases have considerable monthly losses, as seen in Table 4.

Table 4 Income of the electricity services			
Hydro schemes		Diesel sets	
Village	Net Income (US$)	Village	Net Income (US$)
Maria	9	San Martin	231
Shitariyacu	917	San Roque	229
Mayorarca	18	Limabamaba	-154
Chaviña	462	Totora	-291
Santa Catalina	-246	Tambo Quemado	-784
Longuita	-62	La Coipa	-707
Las Juntas	123	Mazocruz	-292

All systems of the survey sample under community management show a positive net income. San Roque, despite spending a significant part of its income on fuel, is the second of the two diesel sets with positive monthly income; also the third highest net income of all the surveyed systems under community management. Among the reasons for this success are: 1) It has a relatively large number of customers, 2) it has the highest tariff among those under community management, 3) it has relatively low arrears (8.3%) and, 4) it saves a very large amount on money due to the high number of down time days during the year.

For hydro schemes, Las Juntas shows a particular healthy performance with a net monthly income of about S/. 400 (US$123) despite the fact that it has only 55 users.

Conclusions

The results of the study reveal that out of the 13 possible critical factors, only 6 are really critical, while the other 7 are important but not critical, as shown in the table. As an example of an important factor, the capacity to pay effects the financial health of a scheme, but it is not critical because in rural villages there is a basic need for lighting for at least few hours each evening, which will be met despite the level of poverty. The connection costs were low for all the systems and therefore have not been a barrier to access to electricity in the surveyed villages. The "important" factors can be overcome if the "critical" ones are working properly.

Critical Factors	**Important Factors**
Management	Effective bill collection
Local capacity (training)	Benefits from electricity on household
Technical Support	Load factor
Source of energy	Capacity to pay
Ownership	Cost of energy
Political interference	Community participation
	Low connection cost

The study reveals that management is most important factor of all, because most of the other factors can be overcome with good management. San Martin and Las Juntas are good examples that demonstrate this. The tariff level is important for the financial performance of the schemes, however the tariffs do not have a direct relation to the consumers capacity to pay. Also payment arrears are not necessarily due to the lack of money of the users, but instead appear to be related to the quality of management. The Las Juntas option (community owned but privately managed) appears to be interesting for small decentralised schemes, because it combines community involvement with effective operation and administration.

The owners of small isolated systems care more about the operation than about the administration of the systems; therefore most of the schemes have at least one operator but very few have administrators. Training for the operators and administrators is generally scarce and poor, being even scarcer for the administrators; this fact contributes to the unreliability of the systems and their poor management.

The study reveals that there is a lack of local capacity for repair and maintenance of the systems and the management rely mainly on external services through consultancies (except for those owned by the government). Community owned and managed systems found it difficult to get these services; some municipalities reported difficulties; the privately run (including Las Juntas) reported no difficulties. It appears that the degree of isolation of the systems plays a role in the level of difficulty to get technical assistance, however it is evident that the capacity of the management is an important factor.

The lack of preventive maintenance programmes is common within all the systems, except for those managed by the concessionaires. The quality of maintenance is worst in community managed systems followed by those owned by municipalities. An exception is Las Juntas, where the maintenance of the scheme is good. All the systems show a high number of down time days per year, except for Las Juntas. Diesel sets generally have poorer reliability than hydro schemes, although often due to lack of fuel.

The source of energy (hydro or diesel) clearly influences the number of hours of service, the amount of energy consumed and the benefits to the community.
People living in villages with hydro schemes clearly have considerable savings in energy budget comparing to those living in villages with diesel sets. This is because on the one hand the operating cost of diesel sets is higher than hydro schemes, but also because those in villages with diesel sets have to expend more in complementary energy sources. The average cost per unit energy is much higher for diesel sets than for hydro schemes. For the sample the average per kWh for hydro schemes is 0.18 Soles (one-third of the regulated rural tariff), while for diesel sets it is 1.61 Soles (three times the regulated tariff).

Hydro schemes provide electricity 24 hours per day in nearly all cases while diesel sets provide only 2 or 3 hours each evening, except for those owned by government, which may provide up to 5 hours. For hydro schemes a high peak demand occurs during the evening hours, but 70 – 75% of the total energy is used at other times. In the villages surveyed, the average electricity consumption per family is five times greater in villages with hydro schemes. In Las Juntas, the demand is lower than most other hydro schemes because consumers are encouraged to use energy-efficient lighting and appliances, so that they get better use of each kWh.

In villages with hydro schemes there is generally good community participation in activities of maintenance of the system; but there is almost none for diesel sets. The main reason is that hydro schemes require some non-qualified skills which can be provided by the users, while diesels require mainly qualified skills, which are hardly available in rural communities. Hydro appears to be a more “community-friendly” technology and more suitable to local capabilities. When a diesel set fails it may need to be transported to a large town for repair, whereas hydro schemes can often be repaired on site.

Ownership is an important issue, which should be clear from the beginning, because it will influence decisions about other issues such as type of management and tariffs. In the sample, most municipality-run schemes have a very poor financial and technical performance poor social performance. The government-managed schemes have a good or at least acceptable technical performance but very poor social and financial management. Community schemes generally have a good social performance but poor financial performance and very poor technical performance, and finally private systems have an acceptable financial and technical performance but very poor social performance.

Political interference in rural areas with promises about grid connection is common. Diesel sets are more vulnerable to political interference due to the few hours of service and significant down time.

Recommendations

- For the implementation of a successful stand alone rural electrification system, management should be considered as the central and most critical issue. Ownership, type of management and relations between stakeholders should be clearly defined.

- Before starting the implementation of stand alone systems it is recommended to examine the existing technical capabilities and implement a programme to strengthen this capacity. This may include the transfer of technology and know how at a regional or national level.
- Building the capacity of the community, especially of the team to run the system, should be taken into consideration from the planning stage and should include technical and management capabilities.
- The management team should be informed about sources of technical assistance: manufacturers, consultants, installers and equipment suppliers; and about the cost of such services.
- Consumers should be made aware of the capacity and limitations of their system, about productive and rational use of energy, about demand growth and the life span of the system.
- Every stand-alone electricity generation system should have a tariff scheme that aims to cover all necessary costs. A flat tariff is recommended as a good alternative to metering, especially for schemes that provide only a few hours of electricity.
- Consumers should be included in decision-making regarding the choice of technology, but the choice should be well informed. They should be given information about the unit cost of energy, the number of hours of supply, the sort of appliances that they can have, and the potential benefits.
- The participation of the people in the design, implementation, operation and management of the scheme is recommended because it appears to contribute to the success of the scheme.
- The management team as well as the population should be made aware of the dangers of political interference.
- Finally, further studies on the replication of the Las Juntas model, community ownership with local private management, should be carried out to find more precisely its strengths and weaknesses.

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