Community Micro-Hydro in LDCs:

Adoption, Management and Poverty Impact

Project 7110

Socio-economic Effects of Micro-Hydro in Nepal, Sri Lanka, Ethiopia and Uganda

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July 1999

Recommendations on the use of micro-hydro power in rural development

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1. Introduction

This report looks at the strengths and weaknesses of the micro-hydro programme in Nepal in the light of the potential for this technology in Ethiopia and Uganda. There is a fast developing programme in Ethiopia, which seems to be following a similar pattern to that used Nepal in the late 1970s, when the programme first started.

This report relates to information which is documented in some of these other reports produced under this project, which are listed below:

1. Proceedings of 1st Uganda Stakeholder meeting, November 1998, ESD
2. Study tour report - Micro-hydro Nepal visit by Ethiopian and Ugandan Stakeholder, December 1998, ESD
3. Uganda Situation Report, January 1999, SDC
4. Proceedings of 2nd Uganda Stakeholder meeting, March 1999, ESD
5. Ethiopia Status and stakeholder report, December 1998, Megen Power
6. Nepal visit report, July 1998, The University of Reading
7. Summary report on micro-hydro status and recommendations in Uganda. June 1999, ESD
8. Summary report on micro-hydro status and recommendations in Ethiopia. June 1999, ESD
9. Socio-economic effects of Micro-Hydro in Nepal, Sri Lanka, Ethiopia and Uganda, July 1999, The University of Reading

2. Background

Energy is an important factor in rural development. Lack of energy is often a constraint that holds people back from achieving a better life-style. Many routine jobs that rural people need to do to provide for their basic needs, demand energy. This energy can be provided manually, which demands hard work from the people involved and takes a large amount of time. An external source of energy releases people from this drudgery and allows them to be far more productive in their use of time [38].

In hilly areas of the world, one source of energy is that from moving water [42]. Small turbine technology has been developed in many countries that can allow both shaft power and electricity to be generated from small streams flowing down hillsides cheaply and efficiently [20, 46]. Shaft power can be used directly to drive machinery that can do many of the tasks that have been traditionally done by hand. The classic example is food processing. Rice hulling, the grinding of grains to flour and pressing of food oils from seeds are very laborious tasks if done by hand. The use of energy allows these tasks to be done much more quickly. The recovery of oil from oil seeds is also much larger if done mechanically.

The availability of energy also allows a range of productive tasks that would not otherwise be possible. New village industries can be set up that can be used to earn income for villagers. Alternative, high value crops and other produce can be grown and processed for sale to towns and even for export. This includes products such as tea or coffee, fruit juices or spices.

Water turbines can also be used to generate electricity. Again the technology for connecting electric generators to turbines and the control and distribution systems have been developed and tested over several years. The size of turbines and the amount of electricity that can be produced ranges from very small systems producing less than 5 kW (called pico-hydro), small village-scale systems producing 5 to 100 kW (micro-hydro), systems producing power for a number of villages, of size between 100 kW and 5 MW (mini-hydro) and full-sized systems, usually connected to the grid. Many mini-hydro systems can also be connected to the grid, if they are sited close enough to make this worth-while.

The availability of electricity to a rural community does offer a range of possibilities for further development. The main use of electricity is for lighting, as electric light is brighter and much easier to use than the alternatives, kerosene or vegetable oil. Electric light allows people to extend their day, allowing productive tasks to be done at night. It especially allows students to study for much longer in the day. However, electric light does not directly earn income and is only required for a few hours a day. It is useful for one or two hours in the morning, so that people can eat and prepare themselves for the working day. It is of most value for about three hours in the evening, when people can do productive jobs. However, electric light can only use 20 to 30% of the available energy from a hydro-electric plant, so other uses must be found for the rest of the energy.

3. Setting up a micro-hydro programme

Purpose

The two major questions that need to be asked when a new rural development programme is to be started are "why?" and "how?". The aim and purposes of the programme needs to be carefully considered to ensure that it does help the people for whom it is intended. The many different aspects of the development programme then need to be carefully analysed and the right processes need to be put in place to ensure that all these different aspects are adequately covered. One major problem in the past with technology-led programmes, such as micro-hydro, has been that the effects of installing the technology on the people has not been adequately considered, or even studied after the event. A second problem with some past programmes is that certain aspects have been neglected, so that the programmes, as a whole, have been weaker than they could have been.

There are several answers to the question why micro-hydro mechanical and electrical programmes have been set up in different countries. A common motive is political; the government wants to be seen as providing development to a remote region, but the cost of grid connection is too high. Micro-hydro electrification is seen as a short cut to providing electricity for these areas, but usually results in a project that is poorly planned and executed. The political approach can be used by both local and national politicians. Local attempts at influencing people by providing such facilities are usually even more badly designed than national programmes. Once the system is built, it is usually poorly maintained and often fails very quickly.

A better motive is to recognise the constraint that lack of energy places on people's ability to develop and find ways in which micro-hydro power, in various forms, can assist people to overcome this constraint. This approach requires that local people are involved in the decision making process and that the end-uses to which the energy is put do help people to improve their life-styles. Such an approach takes time, as people need to talk through all the implications of how setting up such a project would influence their lives.

Methods

How a micro-hydro or any other technology based development programme is set up will also influence its success or failure. All of the aspects of a project must be considered in the planning process and decisions made as to how these aspects can be covered effectively. The neglect of any one aspect can distort the whole programme, cause it to slow down or its costs to rise, or even cause it to fail completely. The various aspects include: technology: its manufacture and installation; extension work and publicity: persuading people that they should become involved; finance: provision of loan funds or even subsidy; follow-up work and maintenance: to ensure the technology continues to work; and socio-economic aspects: the study of how people are responding to the new technology and whether it is doing what was expected.

Such projects require the manufacture or supply of a technology, such as water turbines in the case of micro-hydro. Designs of Pelton wheel and cross-flow turbines that are relatively easy to make in basic workshops are now easily available from groups such as SCAT and ITDG [refs]. However, workshops that are capable of making these designs must be identified and the managers must have an appropriate commitment to the project. Staff need to be trained to make turbines to the appropriate specifications and some means of quality control needs to be maintained over the manufacturing process. If suitable workshops and trained staff are not already available, or if managers are unwilling to commit themselves to joining the programme, then a specialist workshop may need to be set up as part of the project.

If a technology is to be of use to people, they must be willing to own it and use it. Too many technology-based projects have started out as demonstrations, but fail once the demonstration phase is complete, as no-one is willing to take over responsibility for the technology from the agency that has installed it. People need to be motivated to use a new technology; they need to be convinced that it is of use to them and they need to make a financial commitment to use it. For such a technology to be of use to the rural poor, they must be convinced that it will not be drain on their resources, but will help them improve their life-style and offer either a direct cash reward or opportunities to earn such as reward.

The second aspect of a rural energy programme is extension. For a commercial operation, this could be seen as selling a product, but in development terms it is more than that. Extension involves motivating people to use the new technology in a way that will help them improve their life-style, such as by setting up income-earning activities powered by a micro-hydro turbine. For the extension worker, this might involve setting up a co-operative to run the new venture, as well as establishing a market for the products of the venture, if one does not already exist.

Closely connected with extension work is finance. Renewable energy technologies tend to have a much higher capital cost than competing conventional systems, although the running costs are much lower. Rural people must be able to take out a loan to pay the capital cost, but they can usually recover the money to pay back the loan and interest from the money they save running the system. The supply of conventional energy, such as diesel and kerosene, is often subsidised by government, so renewable energy technologies may also need to be subsidised so they can compete. There is often a strong environmental argument for having such subsidies, but this needs to be carefully thought through by government planners and any aid organisation involved in the programme.

If there is financial support for the use of the technology, through loans and subsidies, the job of the extension agent will include helping the individual or group of people involved in the project fill in the appropriate forms to obtain the correct finance. Often rural people find government and bank bureaucracy very intimidating and are not willing to make the approaches by themselves.

Once a person or community has been persuaded to use the technology, the next step is to install it. The installation of micro-hydro turbines demands appropriate skills in site surveying and designing the civil works correctly to match the system. A good system also depends on knowing the energy available from the chosen stream over a full year's cycle. Often the water flow is only measured at the time the survey is done and people are expected to remember how the flow rate varies over the rest of the year. Any alternative uses of the water, such as for irrigation, must also be considered and negotiations made with other users for any water rights that they might have, either officially or through their traditional usage.

The next component of a project is the training of owners, operators and users of the system. Many technical systems have failed because the operators are not taught the best way to run them. The operators need, especially, to know how to do routine maintenance, such when to change oil or how to adjust systems to compensate for wear. There should be support available to assist the operators in case of problems with which they are unable to cope, such as non-routine break-down of equipment. This could be supported by the extension agent, the manufacturer or the installer, but should be easily accessible by the operator, so the machine can be made operational again very quickly. Follow-up visits by this support group to the operators help to build up this contact, provide the opportunity for further training and allow the support staff to assist with routine maintenance work.

The operation of the equipment is not the only area in which support is required. If the micro-hydro system is being used to generate income such as selling services, good accounts are needed to ensure that customers are correctly charged for these services and that the money is used wisely. If a loan has been taken for the purchase of the equipment, then the bank should be able to check that income is available for making loan-repayments. Owners should therefore be training in simple book-keeping and money management.

Alongside the primary tasks that are involved in running a rural energy programme, there are other tasks that should be done. The extension work is greatly assisted if there is a publicity campaign explaining the use of the new technology in the local media, especially via radio.

4. The micro-hydro programme in Nepal

Manufacturing and Technology

The programme was started in the 1970s through the work of two main agencies: Balaju Yantra Shala (BYS), a training workshop set up by the Swiss Association for Technical Assistance (SATA), a programme supported by Helvetas, and Development and Consulting Services (DCS), a programme set up by the United Mission to Nepal (UMN) alongside Butwal Technical Institute

(BTI), another technical training organisation. BYS started with propeller turbines, but after technical difficulties with the design, started using cross-flow turbines, originally designed in Switzerland. DCS became involved in a rural energy project based on cross-flow water turbines about the same time. They were supported by Butwal Engineering Works (BEW), a manufacturing group linked with BTI that has since been absorbed into Nepal Hydro Engineering (NHE).

Both groups quickly recognised a pressing need in the hills of Nepal for food processing, especially rice hulling and flour grinding. Water power had been used traditionally in Nepal for several centuries, using a simple vertical-axis water-wheel called a "ghatta". These were made of wood, with paddle blades fitted into a vertical shaft, driven by water flowing down an open channel. The wooden axle is fitted directly to the upper stone of a grinding mill, which rotates to grind maize to flour. The maize is fed from a wicker basket to a simple feed device, driven by a rod touching the grindstone, so that the seeds are shaken at a steady rate into the top hole of the rotating stone. The typical power supplied by a simple "ghatta" is about 1 kW.

Demands for rice hulling and greater throughputs for flour mills had led to the use of mills driven by slow-running India diesel engines in the hills of Nepal. These were noisy and required that supplies of diesel be transported from the towns, so were expensive to run. The availability of water-driven mills from BYS and DCS was met by a steady demand for their installation in many areas of the country. They were able to compete with diesel driven mills on price and many entrepreneurs were keen to respond to this new business opportunity.

A typical cross-flow system is designed for between 20 and 50 kW of shaft power and is able to drive both a rice-huller and a flour mill at the same time. It is also able to drive an oil press to produce cooking oil from the mustard seed grown by many villagers. Cooking oil is regarded as a high value crop as there is a good demand, especially from the urban areas where fried food has a higher status. The traditional methods of pressing oil, using hand and animal driven presses, require hard work and can remove less than 40% of the oil from the seeds. Power driven oil presses can recover up to 65% of the oil from the seeds at the cost of carrying the oil seeds to the mill, so are very attractive to farmers and for rural entrepreneurs to operate.

Alongside the development of cross-flow turbines, Kathmandu Metal Industries (KMI) developed an improved "ghatta", a metal water wheel mounted on a vertical axis, with shaped buckets. The water was brought through a enclosed penstock, so it emerged as a jet from a nozzle. Various agencies, including RECAST, a group at Tribhuvan University, came up with a similar design, with buckets of a slightly different shape, called the MPPU, multi-purpose power unit, which is also being made by different turbine manufacturers in Nepal. Both improved ghattas and MPPUs can be made to give power outputs ranging from 5 to 50 kW.

There are now seven main manufacturers and installers of water turbines in Nepal, including DCS and BYS. Some existing workshop owners saw the opportunity that hydro-power offered and were given training by BYS and DCS, so they were able to manufacture turbines to the same quality. Senior staff from both DCS and BYS decided they would set up their own businesses and were encouraged to do so. DCS put its main emphasis on installation, so subcontracts most of its manufacturing work to other workshops in Butwal, especially as BEW/NHE became more involved in larger-scale hydro projects. The manufacturers have now formed an association Nepal Micro-Hydro Developers Association (NMHDA) that seeks to maintain good standards for quality by offering training for staff and turbine operators in Nepal.

Further Developments

The effective demand for micro-hydro driven milling systems occurred in the mid-1980s, when large numbers of entrepreneurs saw an opportunity to invest in anew technology that was much cheaper to run than diesel driven systems. However, the demand began to fall away when the best streams had been used. DCS and BYS saw an opportunity to add small electric generators onto existing milling systems. ITDG (Intermediate Technology Development Group) became involved, as they had a simple load controller available that was able to balance the electrical load on a generator by switching in ballast loads. ITDG funded DCS to do field trials of this load controller, while BYS used a similar system that had been developed in Switzerland.

As demand in the midland hills of Nepal began to slow down, manufacturers saw an opportunity to develop turbines for places which had higher heads of water, so introduced Pelton turbines. Again, ITDG was able to help in this area, as they were able to draw on experience from other countries where Pelton turbines had been used. A further development uses a small Pelton turbine directly coupled to an induction generator to form a small-scale "pico-hydro" system which people could install for themselves in a local stream. These "Peltric" sets produce about 1 kW of electricity and can be used to give light to a small group of village houses. Several manufacturers are now producing and selling these sets on a commercial basis.

A more recent interest is in low-head applications of hydro-power, using devices such as propeller turbines. These could be installed in river valleys and other places where there is a good water flow, but it is difficult to ensure a good head for the penstock pipe. BYS, DCS and NHE are looking into this idea, based on low cost turbines developed in Vietnam.

The His Mjesty's Government of Nepal (HMG/N) are involved in establishing large-scale hydro systems for supplying the growing grid-connected urban demand for electricity through the Nepal Electricity Corporation (NEC). In the 1980s, it was recognised that NEC was too bureaucratic to deal with micro-hydro projects, so small-scale electrification was deregulated to allow private and aid organisations to set up systems smaller than 100 kW without requiring a licence. This limit has since been increased to 1000 kW. Some entrepreneurs have taken advantage of this opportunity and built hydro-electric systems to supply villages on a private basis. However, the government has also realised that it needed to organise a community-based programme for the installation of rural electrification projects, so several agencies have been set up to assist in this process. REDP (Rural Energy Development Programme) and RADC (Remote Area Development Committee) are two organisations that encourage village committees to plan micro-hydro systems, supply subsidies for their installation and contract existing installers to manufacture and install suitable systems.

Electronic control systems for hydro-electric systems

An early problem with the setting up micro-hydro-electric generation was the control of the power produced by the system. Large-scale hydro systems use mechanical governors that control the flow of water through the turbines to match the power produced to the demand from the grid. Mechanical control systems are difficult to scale down and smaller versions tend to be as expensive as the larger ones, so the cost per kW rises sharply as the size is reduced. BYS and DCS have tried to produce electro-mechanical systems, but these are still relatively expensive for small-scale systems.

The answer was provided by ITDG, who had access to an electronic load controller (ELC) developed in Britain in the early 1980s. A load controller assumes that the electrical output from the generator is constant and diverts the power that is not demanded by the users to a "dump" load, usually a bank of heaters. Single-phase ELCs were developed that could be manufactured in Nepal and have been fairly successful. Three-phase load controllers have always had a slight problem with instability between the phases, but are supplied with many of the micro-hydro-electric systems made in Nepal. There are only two manufacturers in Nepal capable of making control systems, DCS/NHE and NPP (National Power Producers). Any systems that fail must be brought back to Kathmandu or Butwal for repair. The electronic parts for the ELC are usually imported from the UK by ITDG, so are fairly expensive [19].

In the early 1990s, induction generators were introduced as an alternative to the synchronous machines used in the earlier systems, as they were cheaper and considered to be more reliable. An induction generator controller (IGC) was required and, again ITDG was involved in finding an appropriate design.. IGCs appear to be more sensitive to interference and damage than ELCs, so their reliability is considered to be low by some users [19]. The mountains of Nepal are subject to heavy electrical storms, so all electronic equipment must be well protected against lightning damage.

Since the maximum load on a generator is much more important for a micro-hydro system than the average power supplied, most systems do not charge customers using meters, but use a flat rate tariff, based on current limiting devices (CLDs). Three types have been used in different schemes in Nepal, but while these devices are much cheaper than meters, they add cost to the installation and are not really reliable. Some customers find ways to bypass these devices, often by connecting directly to power lines.

Financial support

One of the reasons for the fast growth of the use of micro-hydro milling systems in the early 1980s was the support of the Agricultural Development Bank of Nepal (ADB/N). The bank saw the need for rural energy as an aid to development of village life in Nepal and gave priority to supporting such programmes, such as micro-hydro and biogas. The bank offered loans for the purchase of the technology and also had technical advisers, who acted as extension agents persuading people to takes these loans to purchase the technology. The biogas programme had a subsidy component, which was also administered by the bank. The micro-hydro programme was considered not to require a subsidy, as several economic studies of micro-hydro driven milling systems demonstrated that they had a high profitability. However, once add-on electricity systems became available, subsidies were provided for the purchase of the electrical equipment, as this was considered a less profitable service to the community.

While the biogas programme proved very successful, from the bank's point of view, as the loan recovery was very good, the payback from small micro-hydro milling systems proved poor. Repayment of loans for electricity systems were even worse. Several studies were done of both systems by ITDG and ICIMOD (International Centre for Integrated Mountain Development). These studies concluded that, while micro-hydro powered milling systems were, on the whole, profitable, poor management mean that many systems were unable to realise their potential. Some owners did not know how to keep accounts and relied on memory to keep track of debtors. Other owners employed illiterate or poorly trained operators to run their mills, so were unable to find out how profitable they were. These owners had set up the mill in order to give themselves political or social prestige in their village, so put a very low priority on repayment of the loan.

These problems highlighted a weakness in the way the micro-hydro programme had been set up, compared to that of the biogas programme, as low priority had been given to training operators and managers of new systems and to detailed follow-up of these systems. ICIMOD, ITDG, DCS and NMHDA have all been trying to overcome this weakness since then, by providing training programmes for anyone involved in the micro-hydro programme. However, this proved too late for ADB/N, who have reduced their involvement in the programme, offering much less in the way of technical and extension support and giving a much lower priority to loans for milling systems.

Financial viability of micro-hydro systems

Many calculations have been made on the cost-benefit ratios for mechanical micro-hydro and hydro-electric systems [15, 19, 23, 32 etc.]. These results show clearly that a food processing mill driven by water power makes much more money over a project lifetime of 10 years than if driven by a diesel engine. The economic viability of a particular mill depends on the local demand for its services and whether there are other mills in the area competing for business. Another major factor is the actual lifetime of the system. A well built micro-hydro system should last for 10 years, with only the turbine needing to be replaced or refurbished after that time. Unfortunately several systems have had the civil works destroyed by floods or landslides, which are expensive and difficult to replace. A hillside after a landslide often remains unstable, so the rebuilding of civil works becomes impossible.

The effect of the apparent high profitability of micro-hydro mills, coupled with the high risks involved, is that it attracts entrepreneurs who want to make a quick profit and who are not committed to maintaining a service to customers. These people take a loan from the bank, use the income from the mill to finance other projects, and are then willing to allow the mill to fail, so they do not have to repay the loan.

Analyses of hydro-electric projects show that the load factor is a major parameter. A typical load factor of 20 to 25% means that most systems are not commercially viable. These systems are heavily subsidised by aid groups between 60 and 80%, with the motive that the area is being "developed" by the introduction of electricity. These plants could become much more financially viable, if the load factor were increased, so new uses for the electricity in rural areas need to be sought.

Quality control

In general, the quality of micro-hydro systems made in Nepal at present seems high, although this has not always been true.. The manufacturers seem to pride themselves on quality systems, using more expensive bearings to extend the lifetime of the turbines, if necessary. Each manufacturer has introduced minor improvements to the basic designs developed by DCS, BYS and other organisations. However, there are weaknesses in other areas.

The design of the civil works is the responsibility of the installation surveyor who directly relates to the customer. These field workers are less senior and are often too heavily influenced by the customer to place the mill in an inappropriate position. Cases of very long supply canals (up to several kilometres), often made across unstable sections of hillside have been reported by teams sent out by ITDG and ICIMOD to evaluate milling systems. Another problem is the measurement of the available water supply for the mill. This is often done during the initial survey for one day in the year, when conditions can vary widely with time. Some water sources are also required for irrigation, so water use disputes can mean that the mill cannot be used to its full extent when other people require irrigation water.

In some cases, turbines and other items have failed because of poor installation. Weak foundations or poor alignment of pulleys have caused vibrations or unexpected loadings on bearings and shafts, which have resulted in excess wear or premature failure of parts. The total quality control of an installation needs to include the complete system, not just the manufacture of the equipment.

The sizing of micro-hydro electrification schemes appears to be another weakness. Few schemes appear to be able to supply the specified power output, so voltages are often low. There is a problem in most rural electrification systems of people stealing electricity, making unauthorised connections to the distribution lines or trying to bypass control systems, so they can use more power than they are allowed. However, even allowing for losses, most systems appear to produce between 60 and 75% of their rated value. Manufacturers do not test their systems after manufacture, so have little idea of the overall efficiency of their turbines or generators. They seem to use a standard equation for power output, based on the water flow and head, that appears to assume much higher efficiencies than are possible with the equipment available.

Follow-up, repair and maintenance

One major weakness of the Nepal micro-hydro programme seems to have been the lack of good repair and maintenance facilities for customers in remote locations. If a micro-hydro system fails, the operators often lack the training and experience to do very much for themselves. Often the turbine will need to be removed and transported to Kathmandu or Butwal, where the original manufacturer or another workshop can make repairs. This can take several days, if the turbine is sited in a remote area away from a road.

The detailed surveys of micro-hydro installations highlighted the poor technical expertise of many plant operators, mainly because owners were not willing to pay a level of salary that would be acceptable to people with any degree of technical education. Many operators were found to be illiterate, so were unable to read any instructions or manuals that might be provided by the manufacturers. While the installers were willing to offer basic training to operators when they were installing the hydro systems, the low salaries resulted in a high rate of turn-over among these operators, so trained staff did not stay for very long.

DCS recognised these problems and have begun to set up service centres for micro-hydro schemes in zonal headquarters in different zones of Nepal. A service centre would have a small workshop, often driven by a hydro scheme, with facilities for repairing turbines, milling equipment and electric generators. It could also be capable of repairing other equipment that local people would be using, such as parts for electric distribution systems, agricultural equipment, vehicles, sewing machines etc. These centres would also act as bases for offering training courses for mill owners and operators.

The whole approach to selling Peltric sets, where a farmer purchases the equipment from the manufacturer in Kathmandu or Butwal and installs it himself, seems destined to incur a high failure rate. While such sets run well when properly installed, many rural people do not have sufficient technical background to do this properly. While detailed surveys of these installations have not been done, ad-hoc comments by individuals walking in the hills suggest a possible high failure rate for these devices. These comments are based on a very small sample (three sets), but the failure rate of this sample was 100% within two or three months of installation.

Extension and motivation

While the installation of a mill or a Peltric set is the responsibility of an individual, so only that person and their family loses out if the system fails, the installation of a hydro-electric generation system often involves a whole community. Organisations involved in these projects have recognised that a community needs to be mobilised and aware of all the implications of setting up a rural electrification system before it is installed. This involves setting up management systems, so that people can be held responsible for running the system, obtaining payment for the electricity produced and ensuring the system is maintained and kept running. Usually a hydro-electric scheme is subsidised from outside, but the local people contribute labour for the civil works that need to be done. A distribution system based on poles taking wires around the village is usually part of the infrastructure of the scheme, but people usually have to pay for the connection between the nearest pole and their house. This can be fairly expensive for poorer villagers, so the take up for connections can be slow.

Various organisations have become involved in this process of mobilising villagers to build and run micro-hydro electrification schemes. UNDP (United Nations Development Programme) is involved in such a project in partnership with HMG/N through the REDP (Rural Energy Development Programme). Their primary task is to build up the community structures in remote villages, so that committees can be set up to install and run micro-hydro schemes. UNV (United Nation Volunteers) have become involved in a similar programme with existing micro-hydro schemes, working with the communities in which these systems have been built, so they can learn to run and maintain them effectively. The RADC (Remote Area Development Committee) is another HMG/N programme that is seeking to do a similar task in the very remote areas of Nepal, close to the Tibetan border. Many overseas aid agencies, such as SNV (the Dutch government volunteer agency), CIDA (Canadian International Development Agency), etc. have provided heavy subsidies for such schemes (up to 75% of the total cost).

Poorer villagers are often very keen to become involved in setting up such a scheme, even if their houses cannot be connected immediately. They expect to benefit from increased services within the village, including lighting of public areas and the introduction of TV and videos in local tea shops and hotels, which they can frequent. One indirect benefit of electricity is that tourists are more likely to visit the village, so creating an increased market for perishable crops, such as fruit.

End uses of electricity

A major weakness encountered by most micro-hydro electric schemes in Nepal has been a very low load factor, often less than 25%. The major demand for electric power is for lighting, but this accounts for only one or two hours in the morning and three or four hours at night. The overall load on the generator for this period often exceeds its capacity, but the demand for power for the other 18 hours a day is very small. Systems using an electronic load controller have an even greater problem, since the ballast load needs to absorb almost all the output from the generator for a large proportion of the time. The ballast load needs to be a device that can absorb variable amounts of power for purposes that can be considered productive.

One application for a ballast load is for heating water. In areas on a trekking route, tourists are keen to pay for hot showers, so the operator of the micro-hydro scheme can make money. In other areas, local people cannot afford the cost of hot water, so this approach is less economically viable. DCS, with the help of ITDG, spent many years developing electric cookers that could act as a ballast load [2]. The initial idea was of cookers that could store heat over several hours, which could then be released when food needed to be cooked. This approach is used in room heaters in Europe, where off-peak electricity is often much cheaper than the standard rate. However, these heat storage cookers were unable to provide the quality of heat required to cook food effectively. The cost of a heat storage cooker is high, as the control systems for getting heat in and out of a storage medium (sand or rock) tend to become complex [19].

An alternative approach was to use a "slow" cooker, in which the food is cooked at low heat for several hours [2]. Again, the quality of heat is variable; especially as the power to the cookers reduces during the evening, when people are ready to eat, so they often have to reheat their food over a wood fire. Since electricity is much more expensive than wood, the "bijuli dekchi" (electric saucepan) has not proved as popular as it was hoped [19]. Its main use seems to be to heat water that can be used for cooking food over a wood fire, thus saving some wood, or for cleaning.

There is a need to find end-uses for electricity in rural areas that provide as good a cost-benefit ratio as food processing from mechanical power. The electricity could be used to drive milling equipment. The extra cost of a generator and electric motors in place of direct mechanical drives can be justified if the power plant is at a distance from a population centre. Groups such as ITDG [45] have looked into a wide range of uses for electricity, but entrepreneurs in villages that have been electrified need to be willing to adopt these technologies.

There are innovative entrepreneurs in Nepal. One mill owner built his own refrigeration plant, using a compressor driven directly from the turbine. This plant does leak R12, a refrigerant that is banned in many countries, as it affects the ozone layer, but it is possible to overcome the leaks. The major problem with refrigeration is that the electric motors that drive the compressors tend to be very sensitive to voltage fluctuations. The quality of the power from micro-hydro electrification systems would need to be much improved to use refrigeration on a scale much larger than at present.

Other schemes have made ropeways to move goods from one place to another driven by motors powered by hydro-electricity. Many villages are built on the tops of hills, while the best farming land is usually in river valleys. The use of ropeways allows crops and other materials to be transported up the hills without the expense and effort of having them carried by porters.

One of the problems in the midland hills of Nepal is that transport from a village to a motor road is difficult and expensive. While many valuable crops can be grown, such as fruit, herbs or spices, the cost of getting fresh produce to a wider market is high. The use of hydro-electricity to process such crops to give them higher value and make them easier to transport is being considered. Fruit can be made into juice, which can be preserved for the journey to the towns. Herbs and spices can be dried or otherwise preserved using electric power. The weak area in this approach, at present, is the marketing of such produce in the main cities. Villagers need the help of government or NGO agencies to allow them to compete with similar produce coming from India.

Cash crops, such as tea and coffee, are grown in Nepal on a fairly small-scale and some producers use hydro-power to help process these crops. Closer links between the agencies involved in encouraging these industries and micro-hydro equipment producers could widen the scope for expanding both the use of hydro power and the people able to benefit from growing these cash crops. A major problem still seems to be the marketing of local-grown tea and coffee in Nepal, as much of the urban population still regard Indian produce as better.

5. Suggested model for the extension of micro-hydro technology

The most effective way of publicising a new technology is to set up a demonstration unit, so that people can see that it works in their locality and this is the approach adopted by many agencies. The way this approach has often been used is to give people the technology and to leave them to use it, after some initial training. The short time-scale of many rural development projects and the demand from the sponsors for quick demonstrable results means that large numbers of units of a new technology are installed, but little is done to ensure they keep on functioning reliably. An effective programme to introduce and encourage the use of a new technology, such as micro-hydro, requires a supervising organisation that can spend many years getting the technology well-established and reliable. This involves, not just the physical performance of the technology, but also the management systems of how the technology is used and financed.

Service Centre approach

Micro-hydro technology has the capability of supplying the forms of energy that is required to manufacture and repair the turbines that generate the power, i.e. either direct shaft power or electricity to drive metal working machinary. The most effective demonstration of the technology would therefore be a small workshop in a rural centre able to manufacture and supply turbines to the area around. Even if the setting up of suitable equipment and the training of skilled technicians took time, such a centre could act as a service and repair centre for a rural area in which a micro-hydro programme was being developed.

Such a centre would also act as a place in which research could be done to develop uses for the power that were appropriate to the local area. If such uses resulted in marketable products, such as processed foodstuffs, such as fruit juices, the centre could act as an agent to assist in their marketting in urban areas. The centre would act as a place in which local people could be trained in the new skills that would be required in order to use the micro-hydro technology effectively. It could also act as a centre for community mobilisers who are involved in helping villages install and run schemes on a community basis.

The first such centre in a country would probably need to be run under the direction of an NGO with aid finance, but the aim should be to eventually transfer the operation of the centre to the private sector. A further aim would be to reproduce these centres in all areas of a country that had potential for micro-hydro development. Each new centre could be set up following a similar pattern to that of the first, although once the operation of such a centre was established, some of the new centres could be set up as privately or community owned concerns from the start.

Technical extension

The programme was launched in Nepal by two technical training institutes (BTI and BYS) looking for appropriate technology items to manufacture. The programme in Ethiopia seems to be following a similar pattern, where staff from the Selam Vocational Training Centre had been to Nepal to locate suitable designs of water turbine that could be made in Ethiopia. Both of the technical training institutes in Nepal had been set up with the purpose of establishing local manufacturing facilities in the country, so were keen to encourage local entrepreneurs to manufacture and install micro-hydro turbines. The manufacturing workshops of both BTI and BYS were formed into private limited companies, so that the staff and trainees had the experience of working under commercial conditions from the beginning.

Even where the overall programme is run under the direction of an NGO, government body or aid organisation, the manufacturing and installation side should be run as commercial companies. The commercial sector imposes certain disciplines that encourage a focussed approach. There may be a need for another organisation that can supervise quality control and act as an intermediary between the development and commercial sides of the programme. This organisation should responsible for writing and administering contracts between the suppliers and customers, to ensure that any failures in quality are put right and the commercial companies provide follow-up and repair and maintenance services required to keep the technology working. This supervisory organisation would initially be the NGO, government body or aid organisation that started the programme. It could eventually be an association of the commercial concerns who are contracted to make and install turbines.

Another task of the supervisory organisation is to find the best ways of using micro-hydro technology to encourage economic and life-style development for the people who are using the technology. This may also require the management of subsidy and loan finances that may be avaiable to the programme.

Financing of a micro-hydro programme

There can be a good argument for a subsidy on the provision of energy to the rural sector. Many governments choose to subsidise other energy supplies, such as kerosene and grid electricity, so alternative energy sources could not be penalised, especially if they are helping conserve the environment. Renewable energy technologies have a high capital cost, but very low running costs, so loan finance on reasonable terms should be available to enable people to take advantage of the opportunites it offers.

The best organisation to handle money for both loans and subsidies is a bank. Banks are already geared to the handling of money and giving out and recovery of loan finance, so the supervisory organisation does not need to duplicate these tasks. However, banks are not usually sensitive to the needs of poor farmers in rural areas and the priorities of economic development, so the task of the supervisory organisation is to act as an intermediary between the banks and their customers in this area. If the supervising organisation is an aid group or a government body, it might be in a position to act as guarantor against some of the loans offered by the bank, to encourage banks to become involved in this type of programme.

Training

If people are to manufacture, install and use technologies that are new to them, such as micro-hydro, they need to be trained in all of the aspects that are involved. These aspects are not just technical, they also involve organisation and management of the use of the technology. If people are to start new businesses, such as food processing mills, they need some basic business and book-keeping skills, so they can keep track of their income and expenditure. It also needs skills in the selling of the services that micro-hydro power can provide and the encouragment of skills and services that are new to the area.

The supervising organisation needs to co-ordinate training courses for all the people involved in using the technology. The other organisations involved in the programme, such as manufacturers and installers and the banks, can be involved in the provision of the training, but the planning of what is needed and what can be provided needs to done by people with a wide overview.

6. Conclusions

Micro-hydro power has proved very successful as a tool to help rural people develop their economic position and improve their life-style. It provides extra energy in a rural area to reduce the drudgery of food processing and it can offer a means of generating electric power in areas well away from the grid. The success of any programme using such a technology depends on a wide range of factors that must all be considered and covered effectively. These include the manufacture and installation of the technology itself, but also making sure the technology is used for purposes for which people have a felt need and which are economically viable. The financing of the installation of the technology through loans and subsidies is another area that needs careful planning over a term of several years.

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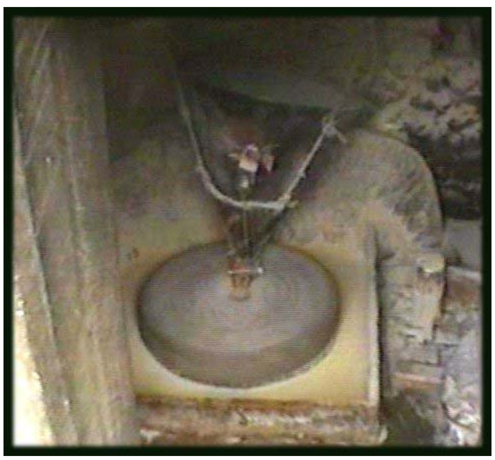
8 Pictures

Picture 1 Manufacture of cross flow turbine

Picture 2 Model of cross-flow runner



Picture 3 Traditional "ghatta" for milling grain

Picture 4 Typical mill site

Picture 5 Oil expeller

Picture 6 MPPU runner