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ITDG

PRACTICAL ANSWERS TO POVERTY

BEST PRACTICES FOR SUSTAINABLE DEVELOPMENT OF MICRO HYDRO POWER IN DEVELOPING COUNTRIES

FINAL SYNTHESIS REPORT
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Front page photograph of micro hydro penstock in Peru (ITDG E3 Peru X4.007).

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The views expressed in this synthesis report are those of **Smail Khennas** and **Andrew Barnett** and do not necessarily represent the views of the sponsoring organisations, the reviewers or the other contributors. Responsibility for the accuracy of the empirical evidence remains with the authors named as the main sources listed above.

EXECUTIVE SUMMARY

This report synthesises the experience of micro hydro developments in Sri Lanka, Peru, Nepal, Zimbabwe and Mozambique. It attempts to draw out the Best Practice from this experience. Micro hydro plants are defined as having a capacity between 10 kW and 200 kW. The report provides a rigorous comparative micro economic analysis of the cost and financial returns of a sample of plants across the five countries. It draws out the macro economic, financial and other institutional arrangements that appear important to the scaling-up of micro hydro investments.

The case study material was provided by nationals of the countries according to a set of methodological guidelines that were developed at the start of the project, in an effort to maximise the opportunities for valid comparisons between the countries. At the request of the World Bank, a British consulting firm, London Economics was contracted to validate the methods used in the financial analyses and to ensure consistency in the data.

Summaries of the micro economic analysis of the case studies of individual micro hydro plants are included in the annex to this synthesis report. The lessons for 'Best Practice' are brought together in summary form in Section 5.

Key Findings

- While the data were not perfect, the report probably represents the most complete *comparative* review to date of micro hydro experience across a range of different countries and conditions.
- Micro hydro technology is now a mature technology that has benefited from substantial improvements over the past 30 years. However, it remains relatively 'unfashionable' and to some extent has been neglected by both major funding programmes and governments.
- The data shows that in certain circumstances micro hydro can be more appropriate and profitable than other energy supply options, and therefore should be treated as part of the 'full menu' of energy options to be considered in meeting the needs of rural people.
- Investment in micro hydro has occurred in three broad phases:
    - a technological phase to improve and demonstrate the viability of the technology;
    - a social phase where the objectives are largely to meet the needs of rural people in just the same way that investments have been made in health centres and feeder roads; and,
    - a financial phase, where the emphasis is on financially sustainable micro hydro investments.

- The successes and failures attributed to micro hydro programmes have been confused as a result of the multiple and wide-ranging objectives set for such programmes. These objectives range from the maximisation of micro hydro regardless of income or need, to providing rural people with electric light because of its social impact and sense of belonging to the modern world, to providing energy that can assist in securing the livelihoods of marginalized people. The unit costs of micro hydro vary across a wide range as they are site specific, and like other decentralised energy systems, in practice the costs are generally higher than those cited in literature. The average capital cost (in constant US$1998) of the sample investigated is $965 per kW[1] for plants used for mechanical power and $3,085 per kW for plants generating electricity, including the costs of transmission, which clearly vary.

- Experience across the study countries shows a wide range of financial profitability and some interesting common features. The microanalysis reveals that there are plants that can be run profitably without subsidy. These tend to be the plant installed initially or solely to produce mechanical power for a profitable end-use such as milling. The micro hydro industry appears, therefore, to be faced with a particularly difficult paradox. Most of the financially viable installations provide mechanical power to productive enterprises, but the main demand from consumers in a number of countries appears to be for electric lighting.
- There are clear circumstances in which micro hydro technology is most likely to be financially sustainable. These include:
    - a high load factor ;
    - a financially sustainable end-use,
    - costs are contained by good design and management; and
    - effective management of the installations, including the setting and collection of tariffs that keep pace with inflation. Ownership is less important for sustainability than business-like management.
- There is clear evidence of trade-off between the price charged for electricity and the number and type of persons that can afford it. This means that there is also a clear trade-off between micro hydro projects capable of meeting the needs of people and those that are profitable.
- Micro hydro appears to exhibit characteristics that indicate: '*it is easier to make the profitable social, than to make the social profitable*'! In planning micro hydro investments it appears important to consider means of using the plant to secure livelihoods at an early stage, and to then see how the impact can be spread to marginalized people and to social activities such as lighting in health centres, schools, etc.
- There is a paradox that the main use for micro hydro appears to be for electric lighting, whilst financial sustainability depends largely on finding a profitable end-use.
- There is a constraint in that costs of micro hydro rise with the remoteness of the location but the cost of alternative options (particularly diesel generators) may rise faster.
- Micro hydro compares well with the alternative energy supply options and has an important niche in the range of decentralised energy supply options. This niche is tightly defined by the availability of adequate small-scale resource and a sufficiently concentrated density of demand, consisting of a need combined with purchasing power, to take advantage of a centralised, albeit small, power plant.
- In its niche, micro hydro compares well with other renewable and decentralised energy options and exhibits the standard characteristics of all renewables,

[1] This figure seems to confirm the US$1,000 per kW benchmark very often quoted without specifying the basis of calculation nor the type of the micro plant (mechanical power, electricity generation) from which the figures are derived.

namely relatively high initial capital costs and relatively low running cost. The strength of micro hydro is that it can provide real power, which can be put to productive end-uses, capable of sustaining livelihoods. An additional strength of micro hydro lies in its mini-grids which can ‘anchor’ or base end-uses to pay for increased access to energy for the poorer parts of the community. This can be done through cross-subsidising the tariff, or more importantly, by powering end-uses, such as milling, that benefit marginalised people, including women.

- Many tasks are required to implement a successful micro hydro programme. These are usefully considered as an extension of the concept of ‘intermediation’. Intermediation not only includes the task of organising the necessary finance, but also technical intermediation, social intermediation and organisational intermediation. These are described in the report and examples of this are drawn from the case studies.
- The analysis confirms that ‘project developers’ perform a crucial role in undertaking the various forms of intermediation. The availability, skills and other capacities of project developers probably sets a limit on the extent to which micro hydro programmes can expand in any country.
- The extent of project developers is largely a function of whether there is enough work for them (is there enough micro hydro plants that can be built and financed each year) and how their costs can be met, either as a fee for service from plant owners, or from specific allocations of ‘soft’ money.
- It was difficult to establish of the scale of a micro hydro programme required to enable project developers and financial institutions to achieve economies of scale in the delivery of their services.
- The costs of intermediation and related ‘transaction’ costs are high relative to project costs. This is in part due to the remote location of the sites and the low density of installations in any particular programme: there is little opportunity for economies of scale in the delivery of these services. This means that there is likely to be a continuing need to combine soft and hard money in micro hydro development. Commercial financial institutions are unable or unwilling to cover the transaction costs of funding micro hydro plants.
- In the case studies, Non-Governmental Organisations led most of the programmes initiated to spread the use of micro hydro. These organisations are essentially tax free enterprises with a commitment to marginalized people. The exception to this is in Nepal where there was an active manufacturing sector and strong, albeit intermittent, support from the Agricultural Development Bank.
- Many funding models were identified and described including: revolving funds; combinations of different types of hard and soft funding from many sources; and innovative ways of dealing with risk and establishing collateral to secure loans.
- Subsidies have played an important role in micro hydro development. The synthesis suggests that there are clear characteristics for the use of ‘smarter subsidies’ that are market promoting rather than market destroying. These are described.
- The case study countries illustrate many characteristics of the ‘enabling environment’ necessary for micro hydro systems to thrive. It appears that there is not a clear strategy for the role of micro hydro in energy sector development or in increasing access of marginalized people to the energy services required for rural development.

- It was not the purpose of the case studies to establish the poverty impact of micro hydro. Whilst the case looks strong it has not yet been rigorously documented.
- The poverty and gender impact of micro hydro would appear to be highly dependent on the choice of the end-uses to which the power is applied.

ABBREVIATIONS AND ACRONYMS

ACAP	Annapurna Conservation Area Project
ADBN	Agriculture Development Bank of Nepal
ADF	African Development Foundation
AID	Agency for International Development
CAPS	Consultancy and Professional Services
CCFT	Cold Comfort Trust
CCO	Canadian Co-operation Office
CEB	Ceylon Electricity Board
CRT	Centre for Renewable Technologies
DCS	Development Consultancy Services
DFID	Department for International Development
ECS	Electricity Consumer Society
ELC	Electronic Load Controller
ENDA-TW	Environment and Development - Third World
ETC	Electricity Tariff Commission
ESD	Energy Services Delivery
FAO	Food and Agriculture Organisation
FGCPC	Fondo General Contravalor Peru Canada
GAA	German Agro Action Aid
GEF	Global Environment Facility
GOSL	Government of Sri Lanka
HH	Household
ICIMOD	International Centre for Integrated Mountain Development
ICS	Improved Cooking Stove
IDC	Integrated Development Consultants
IGC	Induction Generator Controller
IRR	Internal Rates of Return
IRRci	Internal Rates of Return on Capital Invested
ITDG	Intermediate Technology Development Group
ITSL	Intermediate Technology Sri Lanka
IWRA	International Water Resources Association
KMI	Katamandu Metal Industries
KSM	Kwazai Simukai
MCB	Miniature circuit breaker
MH	Micro hydro
MHP	Micro hydro power
MOWR	Nepal the Ministry of Water Resources
NEA	Nepal Electricity Authority
NGDG	Northern Gorkha Development Group
NGO	Non-Governmental Organisation
NHC	Nyafaru Hydro Committee
NMSS	Nepal Machine and Steel Structure
NTH	Norwegian Institute of Technology
ODA	Overseas Development Agency
PV	Photovoltaics
RADC	Remote Area Development Committee

SADC	Southern Africa Development Community
SLEMA	Sri Lanka Energy Managers Association
TV	Television
UK	United Kingdom
UNDP	United Nations Development Programme
US	United States
VDC	Village District Committee
VH	Village hydro
WB	World Bank
WEDS	Water Energy and Development Services
ZERO	Zimbabwe Energy Research Organisation
ZESA	Zimbabwe Electricity Supply Authority

UNITS

A	Amperes
km	Kilometre
KVA	Kilovolt Ampere
kW	Kilowatt
kWh	Kilowatt-hour
m	Meter
Rs	Rupies
V	Volts
W	Watts
Z$	Zimbabwe dollar

1

INTRODUCTION

1.1 The Place of Micro Hydro

Micro hydro, defined as a plant between 10 kW and 200 kW, is perhaps the most mature of the modern small-scale decentralised energy supply technologies used in developing countries. There are thought to be tens of thousands of plants in the 'micro' range operating successfully in China[2], and significant numbers are operated in wide ranging countries such as Nepal, Sri Lanka, Pakistan, Vietnam and Peru. This experience shows that in certain circumstances micro hydro can be profitable in financial terms, while at others, unprofitable plants can exhibit such strong positive impacts on the lives of poor people and the environment that they may well justify subsidies.

The evidence from this extensive experience shows such wide variation in terms of cost, profitability and impact, that it has often been difficult for investors and rural people to determine whether, and under what circumstances, this technology is viable and best meets their needs.

Whilst supplying improved energy services to people for the first time is difficult, supplying such services profitably to very poor people who live far away from roads and the electricity grid poses a particularly difficult challenge. This report shows that micro hydro compares well with other energy supply technologies in these difficult markets. Despite this micro hydro appears to have been relatively neglected by donors, the private sector and governments in the allocation of resources and attention. In the past, rural electrification by means of grid extension was the option favoured by donors. More recently the fashion has switched towards photovoltaics, probably because of its higher foreign content, and the higher added value returned to the metropolitan countries.

The relative neglect of micro hydro has also been in part due to the fact that the circumstances under which it is financially profitable have not been systematically established, at least not in ways that investors find credible. In addition, while it is known that the growth and sustainability of the micro hydro sub-sector depends on certain types of infrastructure and institutional investments, it was often not clear which elements of this 'enabling environment' were essential, nor how they were best financed.

[2] In 1979 the total generating capacity of all small plants was 6300 MW, with 40,000 stations built in the period from 1975 to 1979 having an average size of 85 kW. Ian Juang, draft document on micro power in China, to be submitted for an MSc dissertation, Oxford University, October 1999.

This study attempts to rectify these omissions by analysing and then synthesising the experience of micro hydro over many years, across a broad range of developing countries. Primary evidence was obtained from Peru, Nepal, Sri Lanka, Zimbabwe and Mozambique. On the basis of this evidence an attempt has been made to establish 'Best Practice' in terms of the implementation and operation of sustainable installations.

National teams, usually consisting of an independent consultant and a staff member of The Intermediate Technology Development Group, carried out the work using a common methodology developed at the start of the work. National reports were written separately and were subject to review at national workshops involving the key actors in the sector.

The microanalysis sought to examine a sample of specific installations. The sample was drawn from comprehensive databases of micro hydro plants in each of the five countries. It was selected using a typology which combined end-uses (productive uses, electricity for lighting, combined end-uses, etc.) with types of ownership (community-led projects, projects implemented by central bodies such as the utilities, and projects initiated by private entrepreneurs).

Table 1-1: Summary Table Showing the Sample of Projects Studied In Detail

	Community-led projects	**Top Down-led projects (utilities)**	**Private Entrepreneur**	**Total**
Shaft power only	Zimbabwe (1)		Mozambique (2)	3
Electricity for domestic end uses and services	Sri Lanka (2) Kandaloya Pathavita	Peru (2) Pedro Ruiz Pucará		4
Lighting and productive uses of electricity	Zimbabwe (1) Nepal (1) Peru (2) Sri Lanka (1)		Nepal (3) Sri Lanka (1)	9
TOTAL	**8**	**2**	**6**	**16**

* The numbers in brackets show the number of schemes per country.

Although Zimbabwe and Mozambique have relatively few micro hydro plants operating, it was decided to include them in the sample to illustrate some of the special issues that are faced by countries trying to start programmes. The implication of this experience for other countries is brought together in Section 4.14.

1.2 The Differing Objectives of Micro Hydro Development

One of the most important findings to emerge from the study of this experience is that micro hydro plants can achieve a wide range of quite different objectives. Much confusion and misunderstanding arises when all micro hydro plants are treated as a homogenous category. Analytically it is therefore important to judge the viability of each micro hydro investment in terms of a specific objective. Similarly in the formulation of government or donor policy, it is important not to expect micro hydro to achieve many, often conflicting, objectives. For instance, it is not possible to provide electricity to very poor people in remote locations through micro hydro and make a return on capital similar to that achieved in London capital markets.

1.3 Technology Demonstration, Social Infrastructure, or Small Enterprise?

The field of micro hydro is 'evolving', particularly in relation to the motivation of project developers. Recently the majority of initial installations in each country might be said to be the result of a 'technology push'. That is, plants were installed to test their technical viability and their acceptability. This experience has established the technical reliability of the micro hydro systems, reduced their cost, and has resulted in substantial technical improvement. Micro hydro is now a mature technology that has been greatly improved by electronic load controllers, low cost turbine designs, the use of electric motors as generators[3], and the use of plastics in pipe work and penstocks.

The next group of projects is characterised by investments in micro hydro that were seen as part of the 'social infrastructure' more akin to the provision of health services, roads or schools. Due to their social objectives, these experiences have often generated little information on the capital and operating costs or cash flow returns of the investment, particularly of a form and quality that would be regarded as reliable by potential investors in conventional financial institutions. Indeed many of the promoters of this type of project justify their work solely in terms of contributions to social justice, the quality of life of marginalized people, and to the environment. In Sri Lanka, for instance, many micro hydro plants have been installed primarily to "improve the quality of life by providing electric light[4]". In Peru the key question for many project developers was "how long will the plant last", rather than "how high is its rate of return", or "how quickly the capital will be paid back"[5].

More recently support programmes have returned to what might be called an older vision what might be considered an earlier approach, where micro hydro is seen primarily in terms of securing livelihoods and for the development of small profit-making businesses. This can be seen in part as an admission that, like the previous attempts at rural electrification through grid extension, the sustainability of grant-based programmes is limited. Methods must be established to attract private capital if these programmes are to have anything but a marginal impact. Nepal has shown that small, almost subsistence businesses can survive using micro hydro power to mill grain. Over 900 micro hydro plants had been installed in Nepal by 1996, and over 80% of these were for grinding grain. In recent years there has been quite a rapid take-up of the small (1 kW) 'peltric' sets for generating small amounts of electricity. Introduced in the early 1990's, there were said to be over 250 operating in the first five years[6].

These very different starting points, along with the performance indicators used to evaluate projects, have important implications for what is regarded as a success. Micro hydro as 'social infrastructure' uses the approaches and indicators appropriate to schemes for the supply of drinking water, health clinics and schools. Micro hydro as 'physical infrastructure' uses the approaches applied to electric power generation more generally, and to such investments as the provision of roads and irrigation systems.

[3]See for instance Nigel Smith, *Motors as Generators for Micro Hydro Power*, 1994, Intermediate Technology Publications, London, ISBN 1 85339 286 3
[4] Sri Lanka Report, Section 3.4.
[5] Peru Report, Section 1.1.
[6] See Nepal Report.

Even more recently micro hydro has been seen in terms of small and medium enterprise development, and the role that such enterprises can play in 'securing livelihoods'.

There is little to be gained from arguing that one approach is superior to another, as in all probability each strand has a role to play. But failure to distinguish these very different motivations has lead to confusion and ineffective policy advice. Each approach is associated with very different mindsets of the people involved, and the differing objectives will result in quite different management[7], allocation of resources, approaches and even site selection.

1.4 Hard Choices Have To Be Made in the Allocation of Scarce Resources

Investments that are primarily intended to increase the adoption of micro hydro are likely to need to be financially viable and will therefore be located where there are concentrations of effective demand, or there are so-called 'anchor customers' who can pay for the bulk of the power supplied. This might include sales to the grid where possible and profitable. Programmes that are intended primarily to increase the 'access' of specific groups of people to improved energy supplies are likely to be located where poor live. This will frequently be in more remote areas that will not be reached by the central grid for some time, if ever, where all other options will also be expensive but where micro hydro is the least cost[8].

Examples of the strategy to increase sales, regardless of their income or need, can be found in a number of renewable energy programmes, particularly in photovoltaics. Here it is argued that increased sales will reduce the cost of production, and more importantly, enable the overhead costs of providing technical support and supplying 'retail' credit to be spread over a larger number of unit sales. The danger is that some of the soft money that is intended for social investment is used to subsidise the costs of these supply options for those who can already afford to pay for it.

A key dimension of the trade-off is that the benefits and burdens of the choices made fall on different social groups. The people who can pay the full cost of energy supply often reside in different parts of the country from those with the greatest need. This means that if concepts of fairness are introduced to government policy or, more generally, into the allocation of resources, micro hydro is likely to have an important role in spreading access to electricity, even if the users cannot pay the full cost. The review of programmes in Nepal and Sri Lanka both suggest that they have both been explicitly motivated by ideas of social justice and fairness. Certainly rural people in many countries can be expected to ask why they should not they be entitled to the levels of subsidy provided to urban dwellers.

Micro hydro developers and the financial institutions that they work with have to make choices between these two extremes of profitability and social impact. There is likely to be a middle ground where social impacts can be achieved profitably, but its size is not yet known. What is clear, is that many rural people will remain without electricity unless there is some sort of redistribution of income from urban to rural areas.

[7] See Peru Report, Section 5.

[8] See Peru Report, "there is no guarantee that electrification exclusively under the private sector would increase the electrification rate, although it would increase energy consumption …due to the relatively high consumption of a minority".

There is a parallel here with arguments between the advocates of micro hydro and Ministries of Energy and their conventional utilities. Proponents of micro hydro are often disappointed that utilities will not take them seriously. Certainly micro hydro often faces unfair competition from a highly subsidised grid, and from subsidised fossil fuels. But, there is a genuine trade-off between maximising the access of people to 'efficient and affordable energy', and doing so in those places where micro hydro (and other renewable energy) is the least cost. The scarce resource is not energy, but the capital to make energy accessible. If the objective is to provide electricity to as many people as possible rather than to distribute electricity evenly across the country, the most effective way of doing it may well be through extensions of the grid, or more likely 'intensification' of the use to which the grid is put. Similarly where utilities have very severe limits on capital, the 'opportunity cost' of capital at the margin rises to very high levels, explaining perhaps why they then opt for diesel generators rather than hydro with its higher initial capital cost..

1.5 The Main Forms Of Support – Extending the Concept Of 'Intermediation'

The case studies show that a wide range of actions have to be brought together to ensure the success of micro hydro investments. These actions take place a various levels: at the micro level of particular investment in a hydro plant at a particular location; at the macro level of policy formulation; and in the design and implementation of programmes of financial and other support mechanisms.

In undertaking the case studies, it was found that the idea of 'intermediation' offered a convenient way to group the many hundreds of tasks that were identified as necessary. This provided considerable analytical insight about how policies might be developed to ensure that these tasks were indeed performed and integrated into the costings. The approach extends the idea of 'financial intermediation' and considers three additional forms of intermediation, namely technical intermediation, social intermediation and organisational intermediation.

Financial Intermediation involves putting in place all the elements of a financial package to build and operate a micro hydro plant. A process sometimes referred to as 'financial engineering'. It covers:

- the transaction costs of assembling the equity and securing loans;
- obtaining subsidies;
- the assessment and assurance of the financial viability of schemes;
- assessment and assurance of the financial credibility of borrower;
- the management of guarantees;
- the establishment of collateral ('financial conditioning'); and
- the management of loan repayment and dividends to equity holders.

Financial Intermediation can also be used to cover whole schemes rather than just investment in an individual plant. In this way projects can be 'bundled' together to make them attractive to finance agencies, to establish the supply of finance on a 'wholesale' basis from aid agencies, governments, and development banks, and to create the mechanisms to convert it into a supply of retail finance (equity finance, and loan finance at the project level).

Technical Intermediation involves the 'upstream' work of improving the technical options by undertaking R and D and importing the technology and know-how, 'down' through the development of the capacities to supply the necessary goods and services. These goods and services include: site selection; system design; technology selection and acquisition; construction and installation of civil, electro-mechanical and electrical components; operation; maintenance; Trouble Shooting; overhaul; and refurbishment.

Organisational Intermediation involves not only the initiation and implementation of the programmes, but also the lobbying for the policy change–required to construct an 'environment' of regulation and support in which micro hydro technology and the various players can thrive. This involves putting in place the necessary infrastructure, and getting the incentives right to encourage owners, contractors, and financiers.

The case studies show that this organisational intermediation is also usefully distinguished from the *Social Intermediation*. *Social Intermediation* involves the identification of owners and beneficiaries of projects and the 'community development' necessary to enable a group of people to acquire the capabilities to take on and run each individual investment project.

1.6 The Importance of the Technology

While the rest of this is report focuses mainly on the 'software' of finance, management and social development, it would not be right to end this introduction without stressing the importance of the hardware and engineering skills in the success of micro hydro development. The experiences reviewed here repeatedly confront the need to get the technology right, and develop the technical skills necessary to build, install, operate and maintain the equipment and the associated civil works.

A study on the functional status of the state of existing micro hydro plants in Nepal[9] emphasises the point. Despite much work on manuals, standards, training, and correcting faulty engineering and associated errors, the physical assets remain a substantial cause of failure. A study on the functional status of the state of existing micro hydro plants in Nepal[10] emphasises the point that despite much work on manuals, standards and training, faulty engineering and associated errors, the physical assets remain a substantial cause of failure. Some 30% of the installations were not operating, due in part to:

- Poor site selection, inadequate/inaccurate surveys, wrong size, poor installation, faulty equipment;
- Plants affected by floods and land slides;
- Poor estimation of hydrology, in part due to surveys being conducted in the rainy season;
- Uneconomic canal length, bad canal design;
- Neglect of civil works;
- Inability of owners to replace generators after breakdown; and

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[9] Earth Consult (P.) Ltd, *'A Report of Random Sample to Determine Actual Status of Private Micro Hydro Power Plants in Nepal'*, ICIMOD-ITDG Nepal, May 1998.

[10] Earth Consult (P.) Ltd, *'A Report of Random Sample to Determine Actual Status of Private Micro Hydro Power Plants in Nepal'*, ICIMOD-ITDG Nepal, May 1998.

- Wrong estimation of raw materials, of demand, of end-use possibilities, oversized plants, over-estimation of tariff collection, inappropriate rates, ignorance of competition with diesel[11].

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Turbine Manufacturing in Sri Lanka

Furthermore, there are still a number of unresolved technical issues. In particular there is a trade-off between the quality (and therefore the costs) of the civil works and the resulting costs of operation and maintenance. Low cost civil works tend to be swept away by the monsoon rains and have to be substantially repaired each year. It is not yet clear where the optimum balance lies between these two types of cost[12].

[11] See also Wolfgang Mostert, 'Scaling-up Micro Hydro, Lessons from Nepal, and a few Notes on Solar Home Systems', Village Power 98 Conference, NREL/ World Bank, Washington October 6-8, 1998.
[12] Wolfgang Mostert, personal communication .

2

THE COST OF MICRO HYDRO AND ITS FINANCIAL PROFITABILITY

2.1 The Cost Per Kilowatt Installed

In the examples examined in the five countries, the capital cost[13] of micro hydro plants, limited to shaft power, ranged from US$714 (Nepal, Zimbabwe) to US$1,233 (Mozambique). The average cost is US$965 per installed kW which is in line with the figures quoted in some studies. The installed costs for electricity generation schemes are much higher. The installed cost per kW ranged from US$1,136 (Pucará, Peru) to US$5,630 (Pedro Ruiz, Peru) with an average installed cost of US$3,085. The data for the complete sample and detailed summary of the financial analyses of the 16 sample projects is provided in the annex to this report.

An important observation is that the cost per installed kilowatt is higher than the figures usually cited in the literature. This is partly due to the difficulty analysts have in establishing full costs on a genuinely comparative basis. A significant part of micro hydro costs can be met with difficult to value labour provided by the local community as 'sweat equity'. Meaningful dollar values for local costs are difficult to establish when they are inflating and rapidly depreciating relative to hard currencies. In addition, there is little consistency in the definition of boundaries of the systems being compared, for instance, how much of the distribution cost, or house wiring, is included, how much of the cost of the civil works contribute to water management and irrigation, and so forth.

In this study very great care was taken to produce estimates of the actual costs on a rigorously comparable basis. It is for example of paramount importance to distinguish between schemes limited to mechanical power only and schemes which include electricity generation.

As with any de-centralised energy supply system, the comparison of actual costs at the 'micro' level of individual plants can also be misleading. Successful programmes require investments in the systems necessary for training, repair, and marketing. The critical issue is that these tasks exhibit substantial economies of scale in that the cost per micro hydro plant installed falls as the number of plants increases. Comparisons based on average costs will therefore be strongly influenced by the number of plants built.

Estimates of these 'macro' costs associated with developing and supporting a programme – sometimes referred to as "system overhead costs"[14] are also difficult to establish, particularly as many of the costs associated with Research and Development and the training of engineering workshops are 'sunk costs' which took place over many years.

[13] All monetary values in US$1998 unless specified.
[14] These activities were first identified as "system overhead costs" in the late 1980's, see A Barnett, *The Diffusion of Energy Technologies in the Rural Areas of Developing Countries: A Synthesis of Recent Experience*, World Development, Pergamon Press, Vol. 18, No. 4, April 1990, pp.539-553.

Table 2-1: Summary of Financial Returns on Sample Micro Hydro Plants After Financing

Cost per kW including transmission (US$1998)

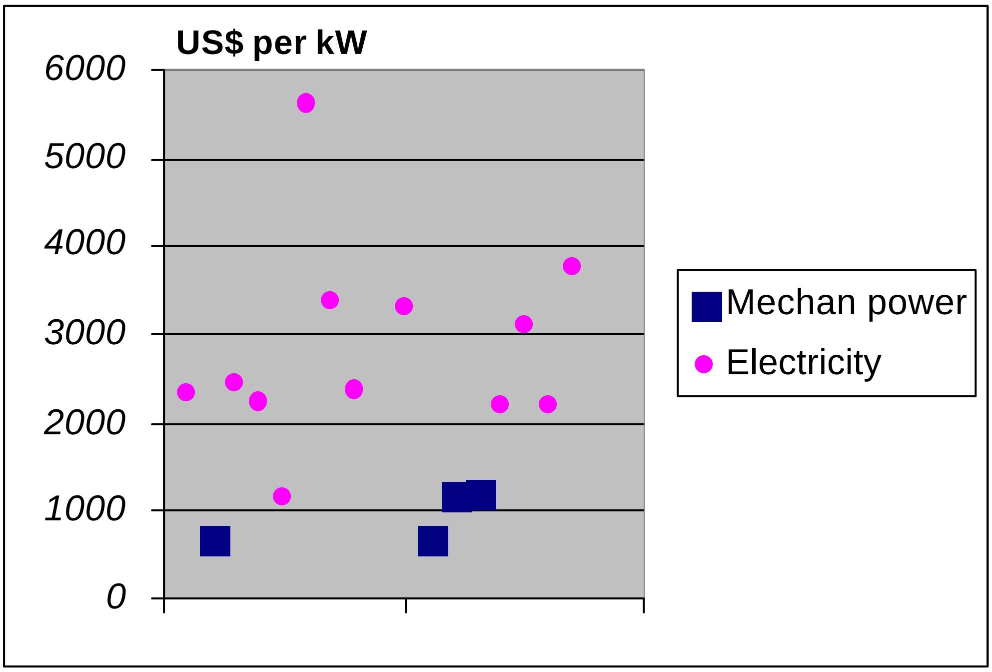
	Year of Installation	Capacity kW	Cost per installed kW	IRR_{CI} %		IRR %		End-uses (main end use cited first)
Sri Lanka				cur	con*	cur	con	
Katepola	1994	35	$2,181	14.7	8	No return		Electricity for domestic end uses and services
Kandal Oya	1997	10	$3,115	15	9.3	10	6.9	Electricity for domestic end uses and services
Pathavita 2	1997	10	$2,203	32	16.3	6	3.1	Electricity for domestic end uses and services
Seetha Eliya	1983	60	$3,761	24	12.4	24	12.4	Tea factory. Electricity for domestic end uses
Nepal				cur	con	cur	con	
Barpak	1992	50	$2,345	33	27	22.8	17	Mechanical power (milling etc); Electricity for domestic end uses
Gorkhe (Rupatar)	1984-6	25	$714	42	32	17.4	4	Mechanical power (milling etc); Electricity for domestic end uses
Ghandruk	1985-8	50	$2,446	10.48	1	No return		Electricity for domestic end uses; Mechanical power (milling etc);
Gaura	1987	25	$2,277	13.2	3	7.39	NA	Mechanical power (milling etc); Electricity for domestic end uses
Peru				cur	con	cur	con	
Atahualpa	1992	35	$2,358		NA	17.5	14.5	Electricity for domestic end uses and services; Mechanical power
Yumahual	1998	11	$3,371		NA	17.6	14.6	Electricity for incubating plant
Pedro Ruiz	1980	200	$5,630		NA	No Return		Electricity for domestic end uses and services
Pucará	1986	2x200	$1,136		NA	7	3	Electricity for domestic end uses and services
Zimbabwe				cur	con	cur	con	
Nyafaru	1995	20	$3,307	Grant		8	NA	Electricity for domestic end uses and services
Svinurai	1993	13	$715	Grant		48	20	Mechanical power only (grain milling)
Mozambique				cur	con	cur	con	
Elias	1996	15	$1,200	NA		insufficient accurate data		Mechanical power only (grain milling)
Chitofu	1995	15	$1,233			insufficient accurate data		Mechanical power only (grain milling)

- All currencies in $1998 unless specified.
- *Calculations carried out in constant dollars 1998.
- In current local currencies apart from Peru and Mozambique which are in current US$.
- N/A applies where the project was funded entirely or to a large extent from non-reimbursable external sources, the IRR on capital invested is extremely high.
- The results regarding the internal rate of return (IRR) and the return on capital invested refer to calculations after financing, when loans were taken up.
- IRR for Mozambique were not calculated due insufficient accurate data.
- For schemes where the producer is also the only consumer (ex. Yumahual in Peru, Seethe Eliya in Sri Lanka) the analysis assumes that the production is sold at the opportunity cost of electricity generated by a credible alternative, either the grid or diesel.

2.2 Wide Variation in Costs

The variations in capital costs have a number of explanations. While common-sense suggests that micro hydro is likely to experience some economies of scale in the size of each plant[15], this cannot be concluded from this particular sample. The main explanation appears to lie in the two types of project, namely: schemes designed to provide mechanical power for productive activities such as agro-processing; and schemes for which the bulk of the production is to supply electricity for domestic end-uses and services. The investment cost for mechanical power is relatively low (US$714 to US$1,233), as there are no transmission lines, connections, or generator. The lowest cost per kilowatt installed were found in Gorkhe, originally built to supply mechanical power, Svinurai, Chifotu and Elias which supply mechanical power only.

Figure 2-1 Installed Cost per kW (US$1998)



Electricity generation schemes, as expected have a higher installed cost per kW. there are also some differences between countries and even within the same country which might be explained by the following parameters:

[15] Economies of scale arising from the size of each individual plant should not be confused with economies of scale associated with the size of the programmes supporting micro hydro expansion discussed in Section 2.1.

- Site characteristics;
- Transport to site (in Nepal transport is said to constitute 25% of total costs[16]);
- The labour content, and the wide variation between the cost of labour in the countries studied;
- Standards[17];
- Sizing (municipal plants in Peru were often over sized); and
- Transmission and distribution costs.

A major conclusion can be drawn from this: *Costs are highly site specific, are controllable with good management, proper sizing and appropriate standards*.

Two other issues emerge from this analysis of costs. In addition to the costs identified here for supplying energy, all systems also require substantial investment in end-use technologies to make the supplied energy useful.

Furthermore, a major advantage of micro hydro is that it can be built locally at considerably less cost than it can be imported[18], and the costs of local manufacture can be reduced still further by developing local engineering capabilities and advisory services. For instance in Sri Lanka imported turbine generating sets up to 100 kW cost approximately Rs.50,000 to Rs.150,000 (US$700-US$2,000) per kW, while the local manufacturers are now capable of delivering them at Rs.10,000 to Rs.15,000 (US$140-US$200) per kW, with marginally reduced turbine efficiencies[19].

2.3 How Do the Costs of Hydro Compare with Other Options?

The picture seems quite favourable to micro hydro. When bringing improved energy services to poor people is the priority, the focus moves to the type of energy services they require and their locations. If minimum lighting is the only energy end-use required in remote locations, photovoltaics may be the main alternative, being cheaper than dry cell batteries, and capable of producing a better light than kerosene. Where falling water is available, micro hydro compares well with photovoltaics. In Peru the cost of 50-Watt systems (modules, regulator, battery, 3 lamps, other components and installation) is said to be $1,020[20]. In South Africa it is currently suggested that the unsubsidised delivered cost of Solar Home systems is approximately US$625 for a 50 Watt system (including battery, controller, wiring and 4 lights), giving a US$10/month break even cost using money at 14% real[21]. This is equivalent to about $12,500 per kW and would therefore appear to be much more expensive than the cost of the most expensive electricity from micro hydro.

Fossil fuels (particularly kerosene) will remain the main alternative to biomass fuel for poor people, as it can be purchased in the tiny quantities and for the small sums of money that are most consistent with poor people's cash availability[22]. Micro hydro, like many other

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[16] World Bank, Rural Energy and Development, page 51.

[17] Tampoe notes that early schemes spent about Rs. 2,000-3,000 on household wiring per household but this increased to Rs. 4,000-8,000 in later schemes in 1996/7 where the CEB standards were applied (Tampoe, M., 1998, unpublished report to ITDG pp140).

[18] However, very inexpensive (but possibly unreliable) micro hydro equipment is sometimes available from China and other countries that are keen to obtain foreign exchange at almost any price.

[19] Sri Lanka Report Section 5.3.

[20] Peru Report.

[21] Personal observation, 1999.

[22] It is perhaps important to note, in passing, the favourable environmental consequences of using kerosene. Professor Kirk Smith and others have shown that a switch from biomass to kerosene and LPG as a cooking fuel would result in a considerable

decentralised renewable energy options, are characterised by high initial capital costs (certainly higher than diesel systems) which are offset to some extent by relative low recurrent costs. This means that 'entry costs' are likely to be beyond the reach of poor people, even if the lifetime costs of these options is lowest[23].

Diesel is the real bench-mark against which micro hydro has to be judged. One of the outstanding features of micro hydro is that under the right conditions it can provide the power (both electric and shaft power) to secure livelihoods through the use of electric motors and other equipment for production. Here the picture is mixed. A comparison with diesel generator sets carried out in Peru shows that micro hydro was the least cost option at the sample sites. It is even more beneficial if the impact on the environment over the lifetime of the project is included. However, the results depend on the cost of transporting the fuel and the cost of capital. A study conducted in Nepal by New Era revealed that five out of the 25 micro hydro plants were not economically viable because diesel generating sets were operating in the vicinity.

In Sri Lanka the cost of diesel generation is estimated to be about US$1,000 per kilowatt installed[24]. However, the lack of trained technicians to provide regular maintenance is currently a major obstacle to their further penetration into the rural environment. Even so, some several thousands electric generators of less than 75 kVA were imported into Sri Lanka in 1996 at a cost of over $10 million.

In practice the crucial factor is likely to be the availability and cost of transporting the fuel, and the extent to which the price of diesel (and the system on which it is transported) is subsidised.

2.4 Micro Hydro can be Financially Profitable

The profitability of the sample projects was measured using both an internal rate of return (IRR) and a return on capital invested[25]. The consulting firm, London Economics (LE), was contracted to design a simple spreadsheet model to generate and test the profitability of the schemes and to assess the quality of the resulting data.
Two types of IRR were calculated:

- In the first calculation all the income is taken into consideration (grants, subsidies etc.). This is the real return of the investment made by the owner. But with this method, schemes that were able to attract a high level of subsidy or grant will have a very high return. When a loan is taken up, the repayment is made according to the agreement with the financial intermediary, usually a bank.
- In the second case, it has been assumed that grants and subsidies are covered by soft loans. This indicator shows what the IRR would be in the case where subsidies and grants are in effect replaced by soft financing facilities.

The two indicators are important because they reflect prevailing and future situations.

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reduction in green house gases (GHG) per person meal. This is due to the considerably greater efficiency with which liquid and gas fuels can be converted into heat for cooking. Burning wood fuel in a normal cooking fire or traditional stove is not "green house gas neutral" because of the products of incomplete combustion (Kirk Smith, et al 1998, Report for the US EPA *Green House Gases from Small Scale Combustion Devices in Developing Countrie*s Phase IIA Household Stoves in India (October 12)).

[23] See Fig 3.1 and Table 4.1 , World Bank, 1996, Rural Energy and Development.

[24] Feasibility of Dendro Power Based Electricity Generation In Sri Lanka, Energy Forum, Sri Lanka, 1998.

[25] See annex.

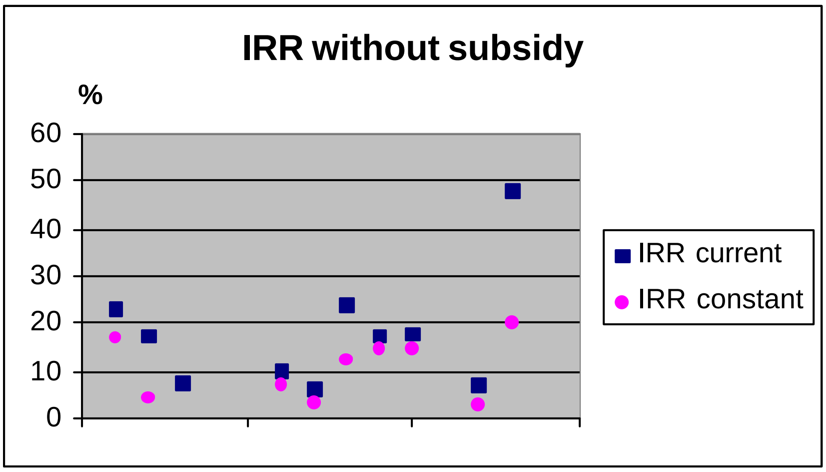
All IRR were calculated after financing. When a scheme was almost entirely financed by grants and subsidies, it has been assumed that the scheme was financed by a soft loan, at rates which vary between the countries in which the plant is located. The IRR were calculated in current and constant US dollars. Assumptions were made about what the inflation rate would be for the lifetime of those schemes that were implemented only recently .

Experience across the study countries shows a wide range of financial profitability[26] and some interesting common features. The microanalysis reveals that there are plants that can be run profitably without subsidy. These are the projects with a constant price rate of return of more than 8%. These plants are Seetha Eliya (12.4%), Barpak (17%), Atahualpa (20.5%) Yumahual (14%) and Svinurai (20%), plus possibly the two mechanical plants in Mozambique[27]. All these tend to be the plant installed initially or solely to produce mechanical power for a profitable end-use such as milling.

Where plants are used exclusively for electric lighting, operating costs can usually be covered by electricity sales, but the capital costs will have to be subsidised by grants.

The analyses in current prices inevitably have higher IRR than those in constant prices. This is because tariff setting is often very poor and therefore the price of electricity is not being adjusted to keep pace with the rate of inflation. An important conclusion of the review is, therefore, that *the financial return of many of the projects could have been improved considerably if the tariffs had been adjusted merely to keep level with inflation.* This is particularly the case in Seetha Eliya in Sri Lanka and Svinurai in Zimbabwe (see Table 2.1).

Figure 2-2: IRR Without Subsidy



At a more fundamental level, *variation in financial performance of the projects reviewed was due to variation in load factor*. High load factors were achieved in schemes supplying mechanical power or electricity to motors rather than those installed primarily for lighting. Lighting for 4-5 hours a day can theoretically give maximum plant factors in the order of 0.15 to 0.20. This is indeed the typical plant factor for many micro hydro plants examined. In Nepal 90 % of the schemes are supplying mechanical power. These schemes have a better profitability and can be financially sustainable in remote locations.

[26] As a result of some gaps in the data and assumptions made, the internal rates should be seen a broad indicators and trends, rather than precise returns actually achieved in each plant. (See annex for details.)
[27] Due to insufficient accurate data, we did not include the IRR for the two Mozambican schemes investigated.

The micro hydro industry appears, therefore, to be faced with a particularly difficult paradox. Most of the financially viable installations provide mechanical power to productive enterprises, but the main demand from consumers in a number of countries appears to be for electric lighting.

Micro hydro is therefore most likely to be profitable or at least financially self-sustaining, where there is:

- a high load factor (the actual consumption as a proportion of total possible generation),
- a financially sustainable end-use,
- costs are contained by good design and management, and
- effective management of the installations, including the setting and collection of tariffs that keep pace with inflation.

2.5 Cash Generating End-Uses.

It is a truism to say that MHP is likely to be more financially viable if the electricity generated can be used to supply power to a profitable cash generating enterprise. The use of a single mill for a few hours per day can clearly raise plant load factors substantially. Furthermore the choice of end-uses can have a profound effect on extending the benefits of micro hydro to households that cannot be connected directly to the system, either for reasons of cost or location. Such end-uses range from street lighting, access to public television, battery charging centres, to mills and other forms of agro processing. However, the studies show that such enterprises are often difficult to develop. Combining new micro hydro installations with new income generating enterprises that have a daytime use for hydro electricity in remote locations is difficult, not least because local markets are small and isolated.

In discussions of this review in Sri Lanka, for instance, both practitioners and policy makers were united in expressing their extreme scepticism about the creation of such enterprises. They argued that:

- Attempts to create electricity using enterprises in the past have tended to increase social tensions within the village and within the management of the Electricity Consumer Societies that own the hydro plant. It is seen as offensive that the public asset of water is being used to increase the power and wealth of an individual.
- Community-owned enterprises, such as rice mills, have often been too large in relation to the local small and isolated market, too costly in relation to the capital available in the village and too difficult to manage in relation to the managerial capacities in the village. It is to assume away the problems of underdevelopment to assume that such enterprises will start up spontaneously after the arrival of electricity.
- The support for small and micro enterprises that is offered in Sri Lanka is said to be limited and could not be assumed to be available to people or groups setting up businesses to use micro hydro plants.

Mechanical energy for grain milling from a micro hydro plant

Similar problems have been experienced about community-owned enterprises in Nepal, particularly where villages contain a wide range of castes[28]. However there have been notable exceptions, particularly in Nepal and Peru were particular entrepreneurs have not only invested in micro hydro, but they have sold power to their neighbours and started up a number of businesses[29].

2.6 Links To The Grid

Sales to the grid represent a special case of cash generating end-uses. Sales, when power is in excess, could provide a better load and the potential for reliable cash flow. The opportunities for selling to the grid are likely to be more feasible at the 'mini', however, than the 'micro' hydro scale.

In one case in Sri Lanka the high returns to one of the plants (Seetha Eliya) was a consequence of the high value imputed to the electricity from the micro hydro plant. The plant provided electricity to the Tea Estate where otherwise only expensive and unreliable power from the grid would be available. In the case of Peru (Yumahual), the high return is due to the opportunity cost from of electricity generated by a diesel generator. The cost per kWh from genset is usually quoted at around 18 US cents per kWh. Of course with such a cost it is likely that the investor would have opted for other options.

[28] Wolfgang Mostert, *Scaling-up Micro Hydro, Lessons from Nepal and a few Notes on Solar Home Systems*, Village Power 98 Conference NREL/World Bank, Washington October 6-8, 1998

[29] See for instance *Private Micro Hydro Power and Associated Investments in Nepal: The Barpak Village Case and Broader Issues*, Bir Bahadur Ghale, Barpak Entrepreneur, Ganesh Ram Shrestha, Executive Director, Centre for Rural Technology and Russell J. De Lucia, Ph.D., President De Lucia and Associates, Inc., *Small-Scale Natural Resources and Related Infrastructure Development* , June 1999, Natural Resources Forum, Special Issue.

In Sri Lanka the Ceylon Electricity Board (CEB) introduced the small Power Purchase Agreements (PPAs) in 1996, and specified the prices they would pay for energy from grid connected small power producers with generation capacities of up to 10 MW. These prices are set by the CEB on the basis of their avoided costs. Consequently the prices vary according to the time of the year and the availability of water in large hydro reservoirs. These prices do not reflect the environmental costs and benefits from small hydro development. The profitability of this option clearly depends on the regulatory framework and the price that the utility is prepared to pay.

In 1999 the prices offered for the dry season were 4.6 US cents per kWh and in the wet season 3.9 US cents per kWh[30]. This would appear to be in line with the average cost of production of a properly run micro hydro plant and with a significant load factor.

Proximity to the grid nonetheless poses its own problems. For many rural people the presence of grid electricity puts the purpose of a hydro plant into doubt. In Sri Lanka it is feared that where an Electricity Consumer Society (ECS) is near enough to the grid to make the necessary connections the ECS members will abandon the MH power and buy directly from the grid at a price that currently is below the cost of production. Similarly in Nepal a study carried out in 1998 found that 38% of the 60 micro hydro plants reviewed were located within 10 km of the grid (particularly in the Central Development Region) and this had an adverse effect on their business[31].

Uncertainty about when the grid will arrive in a village, often as a result of politicians making false promises prior to elections, considerably increases the risk of investing in a micro hydro plant. Such risks could be reduced by government or the utility developing a clear plan for grid extension, and making it publicly available. Similarly where the private sector is involved in extending central grids near to existing micro hydro plants, it will be important to have a regulatory framework that requires the grid to buy power from the hydro plant at a reasonable price, or buy the plant at its depreciated value.

In Sri Lanka it is estimated that in general micro hydro will not be financially viable if the national grid is available within 4 km to 5 km. The cost of grid extension is currently estimated at US$7,200 per km of primary distribution lines.

2.7 Making the 'Profitable' Social is Easier than Making the 'Social' Profitable!

A clear lesson that emerges from the review at this stage is that projects that start out primarily with social objectives find it very difficult to add on profitable end-uses. Micro hydro investments envisaged at the outset as primarily supplying power to a business venture can more easily add on the provision of a social service such as lighting, or power for schools or health clinics.

[30] Source: Government press notices, Daily News, Sri Lanka, various dates.
[31] Earth Consult (P) Ltd. in 1998.

3

MEETING NEEDS AND THE CIRCUMSTANCES OF AFFORDABILITY

3.1 Price and Demand

The cases show that *micro hydro can be profitable, but they also show that when it is profitable it is not necessarily also affordable*. A recent report from the World Bank confirms the view held by many people involved in the practical implementation of rural energy schemes when it says that:

> "*It is illusory to expect that increasing access to electricity for a significant part of the population traditionally excluded from grid based electricity can be financed only by the private sector*"[32].

The case studies support this view. Tariffs that are considered high in relation to local conditions can have a marked effect in choking off demand. In Peru, State owned micro hydro plants charge $10/month, and private companies charge $9/month. It was found that "although the service is reliable, it is evident that the high rates (three times higher than those paid by companies run by communities or municipalities) restrict the service coverage". At these rates only 50% of households can afford power compared to 70% of households buying from municipal plants charging lower rates[33].

A Dutch funded scheme appears to have had a similar experience. The government of the Netherlands has been particularly innovative and an early supporter of decentralised energy options. But its assistance to micro hydro development in Peru does not appear to have been successful. In an effort to push the schemes to a more financially sustainable orientation the scheme had very few takers prepared to borrow at rates of interest which were similar to the normal (high) commercial rates[34].

These experiences lead the Peruvian report to conclude that if the private sector were to take over all rural electrification, they would tend to select the more profitable markets and expand only slowly towards users with lower income using less energy. In their experience private forms of ownership tend to be more sustainable in both financial and administrative terms, but tend to neglect service coverage. Similarly, municipal schemes tend to be less financially sustainable, but when they work properly they tend to have a wider coverage.[35]

[32] *Best Practice Manual: Promoting Decentralised Electrification Investment*, ESMAP World Bank, 1999, Page 10. (See this page also for characteristics of Smart Subsidy.)
[33] See Peru Report, Section 5.
[34] Tarnawiecki, Donald: *Why is Dutch Aid Ineffective in Peru?* In Renewable America No. 2, September 1997, PUC, Lima.
[35] Peru Report.

3.2 The Benefits and Burdens of Remoteness

Even if micro hydro were affordable to poor people with easy access to equipment, advice and credit, it is certainly likely to be more expensive and more difficult for people in isolated rural communities. This is particularly so for families that earn less than US$500 a year in areas where municipal resources are scant. They do not have sufficient information and contacts to identify credit sources, credit terms, existing technical alternatives, etc. These are the typical and recurrent failures of both markets and policies that affect activities in remote rural areas. In this context, development activities with such populations result in high transaction costs for both financial institutions and for the suppliers of equipment and technical assistance, making them unattractive to customers. Consequently, this section of the population is effectively 'excluded' from the market[36].

At the same time this remoteness adds to the costs of all energy supply options, albeit not in the same way. Remoteness increases the comparative advantage of micro hydro relative to other options that require transportation of fuels, or frequent visits from urban-based technicians or revenue collectors.

3.3 The Case for Subsidy

If the price of the energy supplied by micro hydro is too expensive for poor people who need it, then the issue of subsidies and/or grants cannot be avoided. The political acceptability of subsidies has undergone wild fluctuations in recent years. All governments provide subsidies, but it is clear that some have done more harm than good. The essential question that has emerged from the ideological posturing of recent years is less about the rights and wrongs of subsidies in principle, but rather whether a particular form of subsidy actually achieves its intended purpose.

The arguments for using money that is supplied at less than full commercial rates of interest are overwhelming if large numbers of people are to be given access to improved energy services. This 'soft money' will be required to enable people with insufficient purchasing power to gain access to electricity, and to other more convenient forms of energy.

In the most general terms, the reasons why agencies of the state, whether national or multinational, should provide soft money are well known:

- to capture the existence of many positive 'externalities' not reflected in market prices, such as the benefits of health, education, welfare, and environment;
- to redistribute income from richer to poorer parts of the community for reasons of equity and or human rights;
- to kick start an 'infant' industry by enabling the volume of production to be increased and skills developed to the extent that unit costs of production fall to levels where the target consumers can afford to buy them on a sustainable basis in the future;
- to remove or reduce the barriers associated with inefficient operation of the market. Usually including the unequal distribution of information between buyers and sellers, monopoly elements among both buyers and sellers, and hostile features of the 'enabling' environment, such as the unintended consequences of taxes, subsidies to competing options, lack of appropriate regulation, inadequate financial and physical infrastructure, etc.; and

[36] Peru, country report

- to assist users in overcoming the high initial costs of purchases that are 'least cost' when considered over the their operational lifetime.

While subsidies to 'pump prime' markets are quite different from those intended to lower the cost of 'social infrastructure', perhaps the most persuasive argument for subsidising micro hydro is made in terms of 'levelling the playing field' with other competing options and concern about 'fairness'. This arguments suggests that:

- micro hydro should receive subsidies that are equivalent to those received by competing options such as the grid or PV;
- micro hydro needs to be compensated as it is unfairly discriminated against in-so-far as it does not get the same tax breaks and other concessions as other technologies;
- micro hydro needs to be compensated because the full cost of other options is not included in the price. For example, the environmental costs of using fossil fuels such as petrol, or biomass fuels such as woodfuel.

There is also weight in the argument that people in remote locations 'deserve' electricity as much as poor people in other parts of the country. Furthermore, subsidies to micro hydro may well be justified because they are the least cost way of achieving other development objectives, such as motive power to secure livelihoods, lighting for health and education, refrigeration for the storage of food or medicines.

3.4 Limitations of Financial Analyses

The aforementioned arguments suggest that in the analysis of competing options, such as on the basis of 'least cost', conclusions are likely to be misleading if the analysis is restricted to market prices alone. Clearly if the arguments listed here are accepted, market prices for goods and services are unlikely to fully reflect their value to poor people or to the nation. Finding the 'true value' of electricity becomes particularly complex if it is to take into account the so-called 'externalities' mentioned earlier. When externalities are considered, gains are made by, for example, calculating the value of other sources of energy not used (kerosene, dry batteries), and the improvements made to the quality of life of those people switching to electricity from other sources of energy. More fundamentally, prices cannot reflect value if the existing distribution of income is judged to be unacceptable, as this restricts the consumers' communicating their 'willingness to pay' to meet their basic needs, by their 'ability to pay' for them.

Most international financial institutions such as the World Bank accept the validity of these arguments and make the necessary adjustments by using some form of 'economic' or real resource cost analysis in combination with financial analyses based on market prices[37]. However, it is market prices that consumers have to pay to gain access to micro hydro power, and therefore it is important that the regulatory framework brings market prices closer to 'economic' values, and that subsidies compensate for the remaining 'distortions'.

3.5 Filling the Gap Between Full Cost Finance and Free Grants

Before considering subsidies in more detail, it is important to stress two points that have emerged in the current debate. Firstly, the ability of governments, aid agencies or charities to provide subsidies is severely limited in relation to the numbers of people who do not have access to modern forms of energy. Secondly, there is probably more energy-related purchasing

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[37] The World Bank's own approach is set out in L Squire and H.G van der Tak *"The Economic Analysis of Projects"* 1975 John Hopkins Press.

power in poor communities than was previously thought. There is now substantial evidence[38] that people currently excluded from most 'modern forms of energy' do already spend considerable amounts of money to meet their energy requirements, on charcoal, dry cell and lead acid batteries, candles and kerosene, and in some locations, on fuel wood.

This variability in the ability of even poor people to pay for energy services suggests that from a policy perspective it will be important to distinguish at least three types of financial sustainability. In this way subsidies are used to maximise access and are not wasted on people who already have the ability to pay. This approach forms the basis of recent changes in the Peruvian government's policies for rural electrification. In this case the National Electrification Plan established three types of electricity expansion projects, depending on the economic characteristics of the target market:

Class I Projects: Profitable Projects. These projects are intended to make a profit, and under the provisions established in the Electricity Concessions Law, any entrepreneur who identifies a profitable energy project is given the opportunity and the necessary guarantees to implement it.

Class II Projects: Non-profitable but sustainable projects. If these projects are adequately managed they are capable of covering their operating and maintenance costs, even if they do not make a profit. In this case, the State tries to implement joint financing programmes in order to obtain the so-called 'investment commitments' from the private sector. Such projects include those built with State funds but which are subsequently transferred to private or other companies for their operational phase.

Class III Projects: Non-profitable and non-sustainable projects. These are projects aimed at expanding the electrical frontier, for which all that is required is to select technological alternatives that produce the least operating and maintenance costs[39].

The experience in Sri Lanka reflects a similar situation where micro hydro schemes that are designed for industrial activities on the Tea Estates can be highly profitable (i.e. Class I) because of the size of the costs avoided by not using grid electricity. Schemes that supply electricity for rural communities are unlikely to be financially viable without soft money. But even in this sub-market, relatively small one-off grants can result in schemes that can be financially sustainable in this more limited sense (i.e. Class II)[40].

3.6 Smarter Subsidies

If the case can be made for subsidies, experience suggests that the use of soft money can both help the expansion of the micro hydro sector and harm it. As always the 'devil is in the detail' and in the specifics of each context. Hence the phrase 'smart subsidies' [41] has been coined to put some distance between current forms of subsidy and the earlier forms that were shown to stultify innovation, destroy markets, and support the already rich. Examples of this were the subsidies for grid-based electricity, kerosene and diesel.

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[38] For instance from studies in India, Uganda and Zimbabwe undertaken by the UNDP/World Bank's ESMAP programme.

[39] Peru, Section 4.2. However under the current schemes in Peru there is a market segment who are not being served by the systems run by private concession holders, and which are also not included in the medium-term plans of the small systems or facilities run by the State. This is the segment that is currently met by NGO.

[40] Sri Lanka, Section 4.

[41] See Dr Subodh Mathur, Presentation to the World Bank/NREL Village Power 98 Conference, Washington DC, October 1998 and Best Practice Manual: Promoting Decentralised Electrification Investment, ESMAP World Bank, 1999 Page 10.

The key lesson from past experience appears *to be to avoid applying un-ending subsidies to the recurrent costs of micro hydro operation, or more specifically do not directly subsidise the price charged to the energy end-user*.

'Smart subsidies' should be designed in such a way as to re-enforce the commercial orientation of micro hydro schemes to reduce costs and improve service. In most cases this will mean focussing on reducing the cost of the initial investment, thereby increasing the numbers of people who have access to electricity, rather than continuously subsidising the recurrent cost of operation[42].

More generally subsidies that are based on rules and are transparent to all parties and well known before investments have taken place are less likely to result in waste and corruption.

It is also important to consider a wide range of ways in which the costs of the whole micro hydro development can be reduced, and not just be a subsidy to the providers of finance. Providing subsidised assistance for the training of turbine manufacturers, or independent on-site feasibility studies appears to be particularly effective in reducing costs to the user, and in reducing the risks to the investor.

A particular problem with current subsidies provided by bilateral donors is that they have a tendency to 'pollute the well' – that is, they use their subsidies to spoil the market for others. This can occur if aid subsidies are available to a particular technology thereby making it very difficult for other technologies to compete. This again happens where subsidies are tied to a particular supplier, usually nationals of the donor country, thereby giving them an unfair advantage. Donor subsidies are currently even being awarded to huge multinational corporations in a number of areas of renewable energy and in particular countries, which makes it particularly difficult for smaller local suppliers to compete.

3.7 The Poverty Impact of Micro Hydro

It was not the intention of this study to measure the poverty impact of micro hydro. However David Fulford, Paul Mosley and others have recently attempted this very difficult task in a parallel study commissioned by the UK's Department for International Development. As these authors point out, it is conceptually and empirically difficult to attribute measurable poverty impacts to relatively small investments, such as micro hydro. This is because in such cases there are many other circumstances, such as climatic variation and macro economic change that affect the measurable poverty status of remote communities over any particular time period.

However, these researchers used a 'second best' approach, consisting of tracking, by partial equilibrium methods, the effects of micro hydro on the incomes of the poor through changes in entrepreneurs' incomes, labour incomes, consumer real incomes and backward and forward linkages. Following this approach the researchers found:

> "*in relation to the number of schemes in existence the poverty reduction performance of micro hydro is impressive, particularly in Nepal and Ethiopia….micro hydro is indeed a relatively efficient method of poverty reduction, in terms of costs per person moved across the poverty line. The poverty gap measure suggests that micro hydro is also able to reach a number of the extremely*

[42] Lifeline tariffs may well be an exception to this, but may be justified where the subsidy is essentially paid by a "cross subsidy" from richer consumers, so preserving the idea that the whole enterprise covers its operating costs.

poor…. through the channel of wage employment in micro hydro schemes themselves and linkage activities derived from those schemes. In addition, we believe that the estimates of poverty reduction from micro hydro.. systematically understate poverty impact, as they exclude a range of very difficult to measure but important effects such as time savings from no longer having to carry kerosene or other fuel, improved education from the availability of electric light and improved health and agricultural production from drinking and irrigation water made available out of channels originally developed for micro hydro schemes."

"On the preliminary data presented here, therefore, there would seem to be evidence enabling a poverty reduction case to be made for the promotion of micro hydro, in particular through the policy instruments specified. Whether that indeed turns out to be the case depends on whether the estimates presented here can be validated by a broader range of data, both from the countries considered here and elsewhere".[43].

3.8 Gender and Micro Hydro

The five country reports provide little or no gender disaggregated information. However one of the authors had carried out a path-breaking piece of research on the gender related impact of micro hydro in Sri Lanka in the mid 1990's. This covered a sample of 5 plants, selected to represent different income levels and end-uses. Unfortunately only one of the sampled plants was also covered in the more recent survey (Pathavita)[44]. A random sample of some 86 connected and unconnected households were investigated (within which a sub-sample of 45 households was selected where both male and female members of the household were interviewed).

While participation in village activities was generally found to be higher for males than females, the sample showed a wide variation between the villages in the extent of female participation in the hydro schemes. As might be expected, those households that are connected to the hydro system participated considerably more than those that were not. Generally males dominated the planning and initiation stages of the projects. In some Electricity Consumer Societies women were "not regarded as decision makers" while in others they were encouraged. ECS meetings were frequently held on weekday evenings, which were particularly difficult for women to attend. Technical issues were frequently regarded as "male".

The benefits were largely at the household level (lighting, TV and battery charging) for connected households, but unconnected households benefited by access to TV and the possibility of hiring lights for special occasions. Women tended to see the benefit of electricity largely in terms of reducing their workload, health, reduced expenditures. Whereas the men saw benefits in terms of leisure, quality of life and the education of children. In connected households the benefits of lighting ("a public good") were equally distributed between males and females, but in unconnected households, the males were able to obtain more benefit as the women were often excluded. Most Perhaps the most important finding was that the impact upon unconnected households was greatly affected by the choice of end-uses. For example, it

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[43] *Micro hydro generation as instrument of poverty reduction: Asian achievement and African potential*, by David Fulford, Alistair Gill and Paul Mosley, Reports to DFID, Reading University.

[44] Kiran Dhanapala, 1995, *Report on the Gender Related Impact of Micro Hydro technology at the Village Level,* Intermediate Technology, Study Report Number 2, 59 pages.

is suggested that the addition of a chilli mill would probably produce more benefits to the excluded group than say the addition of a battery charging station.

The survey showed that typically less than 50% of the households benefited from micro hydro, re-enforcing village level power structures or increasing friction within the village. This evidence has implications for poverty alleviation policy. Earlier we saw the impact the chosen end-use had upon the type and distribution of benefits between households and between men and women. Together these observations underline the importance of including both women and non-connected households in the decision-making process if poverty impact is to be maximised.

In Nepal, an assessment of the impact of Gandruk hydro plant suggested that the advent of television had a significant 'cultural impact'. Women could see that they, "don't have to remain as second class citizens"[45].

[45] *Social Impacts of Electrification: Micro Hydro in Gandruk, Nepal*, by Joshua Thumim, MSc Thesis, 1999, Imperial College London. In this case only one quarter of the households were electrified, with the richer households consuming more power than the poorer ones. Thirty households were interviewed (of which some 30% of the interviews were with women). The data are not disaggregated by gender.

4

INTERMEDIATION IN PRACTICE: EXPANDING THE USE OF MICRO HYDRO

4.1 Many Dimensions

A variety of approaches have been used to diffuse micro hydro. The chosen strategies vary according to local circumstances and how long the programmes have been going. In the early days the approach typically involved a small group of enthusiasts (usually engineers in NGO) who raised awareness of the possibilities by building and demonstrating plants, while more mature programmes involved strong interactions with the main agencies of government and development assistance. Broadly speaking each strategy involves a combination of the following five elements:

Project Promoters:	• Government owned utilities • Non-Governmental Organisations • Equipment manufacturers • Individual entrepreneurs • Multilateral or bilateral aid agencies
Financing Mechanisms	• Formal development bank loans and grants • Grants from charities • Equity from private (local) savings and contributions in kind
Plant Owners / Managers	• Utilities • Municipal authorities • Existing formal businesses such as Tea Estates • Individual (village based) entrepreneurs • Village or community groups
Technical Support Mechanisms	• Change agents (Village Catalysts, barefoot engineers) • Engineering workshops • Existing consulting engineers • NGO
Main End-uses	• Domestic lighting / radios • Social services (to schools, health centres, street lights) • Productive end-uses, usually using motive power

4.2 The Main Diffusion Strategies

The uncertainty surrounding the best method of expanding micro hydro was due to a number of factors: the situation was changing rapidly; the current strategies were not necessarily fully documented[46]; and due to the number of different actors involved, each with a different strategy, some of which were implicit rather than explicit.

In most cases it would appear that the governments in the countries examined do not have policies specifically for the development of micro hydro. Although some had policies to encourage rural electrification, these were usually through grid extension. Where there were policies to support a particular technology, such as solar photovoltaics, these tended to be driven by external donors.

The main elements of the current expansion strategy can be characterised as follows.

Summary of Strategies to Expand the Use of Micro Hydro Plants in Selected Countries	
Peru	An NGO led strategy based on a revolving fund financed by the Inter-American Development Bank. • The Government's Executive Projects Directorate (DEP) created a strategy for isolated areas (1997-2000) but in practice this focuses largely on mini hydro power plants (60) and diesel generators (72). • There is no explicit strategy for the smaller, micro hydro power. • The regulatory framework is aimed at promoting private investment in generating and distributing electricity but the Government's clear preference is to support grid based electrification.
Sri Lanka	A long standing programme in many phases: • Initiated in 1979 by the Alternative Energy Unit of the state owned utility. • Followed by an NGO-led strategy based initially on the refurbishment and demonstration of MHP in the Teas Estates and subsequently on workshop training programmes and the creation of village-based Electricity Supply Committees (#check name) • A Technical Assistance Committee (subsequently Energy Forum) provided co-ordination and direction between government, NGO and private companies. • The current phase based on World Bank funding of more commercially orientated approaches through the Energy Services Delivery Project operated by the Development Finance Corporation of Ceylon.
Nepal	A long standing programme based on: • The provision of subsidies to micro hydro through the Agricultural Development Bank of Nepal (ADB/N). • Credit support through the ABD/N. • NGOs drove the sector, and combined building-up the capability of the local turbine manufacturers with the development of a number of

[46] Peru, page 9.

	technical improvements (the electronic load controller and the use of electric motors as turbines). • A significant part of the sector (turbines for milling grain) is financially self-sustaining, and receives no subsidised support. • The current phase of the strategy involved the creation of The Alternative Energy Promotion Centre (AEPC) in 1996 as an autonomous body under the Development Committee Act, and is overseen by the Ministry of Science and Technology (MST). The mandate of AEPC is to promote renewal energy technologies to meet the needs in rural areas of Nepal. DANIDA is assisting those elements of the programme that promote micro hydro development and PV.
Zimbabwe	An NGO led strategy, currently at the early stage of awareness raising and the construction of demonstration plants. • An important element of the strategy is the Energy Forum of Zimbabwe (EFORZ), originally the Hydro Forum. The forum draws its membership from interested individuals, NGOs, government departments, universities, tertiary education institutions, research institutions and the private sector. EFORZ works closely with government on policy and planning of micro hydro development.
Mozambique	An NGO-led strategy, currently at the early stage of awareness raising and constructing demonstration plants. • The development of new and renewable sources of energy is a result of isolated initiatives and no institution has staff oriented solely to these activities. The Government is investigating alternative methods of supplying household and small industrial concerns with energy. • A local NGO, KMS, funded by FOS-Belgium, is working with ITDG to rehabilitate a number of schemes to raise awareness and demonstrate the technology.

4.3 The Key Agents Behind The 'Strategy'

The case studies showed that even the most modest hydro development programme is likely to involve many stakeholders: government (national and local); utilities; project owners and operators; aid agencies; financial institutions; equipment manufacturers, assemblers and suppliers; providers of Technical Assistance; contractors plant owners; community developers ('animators'); communities; and the beneficiaries.

Agents of the state have played a particularly significant, if intermittent, role in encouraging micro hydro. In Nepal, the Agricultural Development Bank appears to have been the lead institution, drawing on the services of NGOs. In Sri Lanka, the utilities (the Ceylon Electricity Board) similarly expressed an early interest in micro hydro and then drew on the services of an NGO and local consultant engineers.

The international financial institutions, both multilateral and bilateral, now appear to be taking an interest in micro hydro. In the 1960's and 1970's these aid agencies invested heavily in rural electrification, but this was almost entirely through grid extensions. This experience, and particularly the sense that rural electrification was a bottomless pit of financially unsustainable projects, meant that they remained reluctant to fund more recent, decentralised systems.

E3 Sri Lanka L2.11

ITDG

Installation of hydro system in Sri Lanka

However, they have begun to re-consider decentralised energy options, prompted no doubt by their new interest in renewable sources of energy[47] and by the enthusiasm of manufacturers of photovoltaics in industrialised countries.

In Sri Lanka the World Bank included micro hydro in its Energy Services Delivery loan, which was initially envisaged to cover only solar PV. In Nepal substantial funding is now coming from Danida aimed at increasing the scale of the effort devoted to micro hydro (and PV), and to put the schemes on a more financially secure basis.

4.4 The Issue of Ownership and the Main 'Clients' of the Strategies

The cases show that there is a wide variation in the types of actors that own and operate MHP and that this determines both what support they require, and also the objectives that they are attempting to achieve, and even the cost at which they do it.

In Peru the municipal authorities have played a particularly important role in owning and operating micro hydro installations. This is partly because they are the entity that has access to government funds and can raise local resources through taxation. The municipalities are usually district or provincial capitals with a population that usually exceeds 500 people (100 families). The electricity services managed by them tends to have a greater coverage (higher electrification coefficient) than those operated by 'peasant communities' or private operators, because the Mayors tend to justify themselves by providing services to as many families as possible.

However, this political factor also has negative consequences, as there is a change over of Micro Hydro operating staff at each change of mayor (re-elected every four years). Furthermore, access to central government funds means mayors are under no pressure to charge cost-covering rates for the service and generally politicians are reluctant to raise tariffs. All but one of the municipal plants reviewed had a negative financial balance and high rates of outstanding payments (23%) even though rates are relatively low, equivalent to $3.2 per month per user.

In Sri Lanka in village hydro schemes, the ownership, management, financial control and load regulation are carried out by the Electricity Consumer Society (ECS). These are societies

[47] Interestingly the enthusiasm for "new renewables" has taken place at time during which lending for conventional scale hydro electricity has declined rapidly. This probably means that there has been a net fall in donors' contribution to energy supplies from renewable sources. See, for instance, World Bank Operations Evaluation Department Report No. 17359, Feb. 1998, on Renewable Energy, pages 57 and 58.

formed by the villagers that consume the power delivered by the village hydro plants (see Box). However, under the more 'commercial orientation' of the World Bank programme, the ECS were not eligible for loans and have to be converted into limited liability Electricity Consumer Companies (ECC). An unfortunate consequence of this is, apparently, that the consumers feel less like 'owners'. There is less motivation to stay with the village hydro scheme or to pay back the loan, as responsibility lies with the ECC[48].

Where utilities are the owners or substantial contributors to micro hydro, there is a tendency for the technical standards to be higher, thus raising the cost of supply substantially[49] (see Section 4.13).

Private owners have also played an important ownership role. For instance, Tea Estates have been particularly important in Sri Lanka, as many of the initial micro hydro plants were located there and their refurbishment enabled the technology to be demonstrated, and experience to be gained. However, private companies have had difficulty in getting the necessary approvals to use publicly owned resources such as river water or the river bank (which in Sri Lanka at least is usually owned by the state), or the necessary 'way leave' to allow conductors to cross a public road. Individual owners may face similar constraints, but they have also been important players and have successfully developed and owned micro hydro businesses (see footnote 29).

The case studies also contain many different forms of ownership and different styles (and quality) of management. This is particularly taken up in the Peru report (Section 5). Generally the reports do not support the view that there is a relationship between the quality of management and type of ownership. Small owner operators tend to have weak management (e.g. in Mozambique), while politically dominated management experienced in Municipal plants and co-operatives are likely not to raise tariffs with inflation.

Experience around the world suggests that it is possible to have efficient 'business-like' management, whether the plant is owned by individuals, state-owned utilities, or community groups. The lesson from big utilities is to ensure that the regulatory authority is able to produce the incentives necessary for effective management. In the smaller decentralised systems, such as micro hydro mini grids, this also probably means setting up (corporate) structures that minimise political interference, and provide clear delegated authority to a management to achieve clearly stated objectives (related to profitability, coverage and the quality of service).

4.5 Intermediation and the Critical Importance of 'Project Developers'

But perhaps the most important 'agent' in the implementation of strategies for micro hydro has been the 'project developer'. 'Project developers' are the people or agencies that: identify the sites; help organise the community into an organisation (such as the Electricity Consumer Societies in Sri Lanka); act for the community or plant owner to arrange the finance; obtain the equipment; supervise design and installation; train the operators; and press for change in the regulatory environment, etc.

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[48] The ECC at Pathawita is facing a severe threat to its existence with the national grid penetrating into its area. The loss of existing consumers and the difficulty of attracting new customers may result in difficulties paying back the 8-year loan under the ESD program.

[49] Tampoe notes that early schemes spent about Rs. 2,000-3,000 on household wiring per household but this increased to Rs. 4,000-8,000 in later schemes in 1996/7 where the CEB standards were applied (Tampoe, M., 1998, unpublished report to ITDG pp140).

NGOs have been major suppliers of 'project development services' as they saw the provision of these services as a necessary step in demonstrating the technology, or as their contribution to helping a specific group of marginalized people gain access to improved energy supplies. However, there are also important cases where individual entrepreneurs have acted as their own project developers[50].

Almost regardless of the financing mechanisms or the strategies of governments and aid agencies, the critical factor in the development of micro hydro programmes has been the existence of the aforementioned individuals or agencies. They have had the skill to put the various elements of a micro hydro project together and the tenacity to see it through to operation. This suggests another key conclusion: the rate at which the micro hydro sector can be expanded will be dependent on the rate at which such project development capabilities can be developed, expanded and paid for.

4.6 Transaction Costs and the Cost of Intermediation

While the case studies showed the importance of the various types of intermediation, they also showed that there was very little knowledge about how much each of them cost. For instance, the long process of technology development and capacity building took place over many years and involved substantial investments by the companies involved, institutions such as the ADB/N, numerous aid agencies and international NGOs. No estimate has been made of the amount involved, but if micro hydro is to be successful in other countries similar investments will have to be made.

Similarly the costs of 'animating' the communities to own and operate micro hydro installations is difficult to establish, but again the investment is likely to be considerable and the process likely to last many years, with each community.

A key conclusion therefore is that finding the funds to cover the costs of intermediation is likely to be a key factor in the successful introduction and scaling up of micro hydro programmes. As with other decentralised energy options, private financial institutions cannot or will not cover the cost associated with many of the transactions necessary to get these energy options installed. Indeed many financial institutions will probably have considerable difficulty even in covering the relatively high transaction costs of 'retailing' their capital resources to the people who want power from micro hydro plant.

This situation is well illustrated by the case in Sri Lanka. When the World Bank funded the Energy Services Delivery (ESD) project, the supervision and certification of loans became a major cost element. Many of these tasks were originally carried out 'for free' by Intermediate Technology for both village people and financial institutions. With ESD they either had to be supplied at very much greater cost by local consulting engineers or did not take place at all. This meant that the draw down of the loan funds was very low until additional funds were made available through a grant from the Global Environmental Facility (GEF). After this point, it was possible to undertake the tasks associated with loan monitoring, and the establishing of title to land for the purposes of providing collateral for the loans.
Similarly in Peru relatively few people initially applied for support from the IDB funded revolving Credit Fund. The 'marketing' programme that was then initiated required a considerable effort of visits to the target areas. Luckily it was possible to cover the costs of this with non-reimbursable funds provided by the IDB. In addition it would appear that for every

[50] A particularly interesting example is that of Bir Bahadur Ghale, from Barpak in Nepal, referred to in footnote 29.

$100 spent on a micro hydro plant in Peru (from grant or loan) an additional $15 is currently spent on the system over head costs (for a $36,000 plant these costs would be $5,400).

But private entrepreneurs who develop their own projects also incur huge intermediation costs. The most fully documented case is in Nepal where a private individual took about two years to develop a basic micro hydro scheme. During the period, according to his own account, he made 'forty-one trips to Kathmandu to meet with suppliers, government officials, bankers and others including ITDG in order to build his scheme'[51].

Such activities are systematically omitted from the estimation of costs in the comparison of options for decentralised energy supply (see the earlier discussion in Section 2.1). The result is that no account is taken of the size of a programme that is necessary to capture the economies of scale associated with the provision of the necessary elements of 'intermediation' (see footnote 15).

In the case studies reported here an attempt was made to identify all the activities associated with the installation and operation of the individual plant (and quantify the associated costs), and all of the various actors who performed them (manufacturers, contractors, plant owners, customers and other beneficiaries, government, banks, utilities, and the various 'intermediators').

4.7 The Size of the Micro Hydro Market and the Sustainability of Current Support Mechanisms

The relatively high cost of intermediation frequently means that the tasks of project development will often fall to NGOs. Certainly it is NGOs that can most easily access the soft money that these projects will need if poor people are to benefit from them. But it will also often only be not-for-profit agencies, such as NGOs, that can cope with the high transaction costs involved. The costs of these 'intermediation' activities are frequently absorbed in the general programme costs of NGOs and cannot be separately identified. Indeed none of the NGOs investigated could tell the researchers how much they had spent on this type of general support activity over the many years that they had been involved. This means that NGOs will not be in a position to scale up their operations, not only because such activities are dependent on the size of the grants they receive, but also because installing hydro plant is rarely the sole purpose of these NGOs.

This raises the critical questions of whether NGO dominated programmes are in fact sustainable in the longer term, and whether such programmes can be scaled-up without adequate funding for more mainstream and commercial project development mechanisms. The current reliance on NGOs is often too ad hoc and the programmes too small to capture the economies of scale, in these 'system overheads' costs. This is likely to prove a difficult barrier to overcome when the programmes are to be scaled-up and these costs dealt with on a more commercial basis.

In principle these project development functions could be spun off into separate entities, either single purpose NGOs or consulting firms. But it is precisely these entities that have proven to be so difficult to fund in the past[52]. It is not yet clear whether there will be enough work for

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[51] See reference in footnote 29

[52] In one of the most innovative programmes to create business plans for the renewable energy businesses in Africa (FINESSE) the main constraint appears to be the lack of institutions who can operate as project developers working between the people

such businesses to be run on a financially self-sustaining basis. There is great uncertainty about the size of the micro hydro market, particularly as the demand will be affected greatly by the level of soft money available and how the money is used.

Many of the estimates of the potential for micro hydro are based on overly simplistic views about micro hydro potential, based solely on approximations of appropriate sites with falling water. For instance, in Sri Lanka conservative estimates of the technical potential of MH are about 80-90 MW. But these estimates do not include the costs of harnessing this potential. As with other energy resources, such as PV or natural gas, there is rarely a shortage energy, but rather a shortage of the skills and capital to make use of it.

In Peru market development is said to be limited. This is in part due to the lack of information on consumers that fall between ‘real’ markets (profitable and in charge of private concession holders) and consumers whose only chance of gaining access to electricity (in the medium term) is a state subsidy. In at least one case, the government over estimated the demand and offered a concession. However, when the grid extension projects were implemented, it was found that the demand was much lower than anticipated and in some cases non-existent. The State ended up covering the deficit.

In the case of Sri Lanka an attempt has been made to develop the capacity to perform some project development tasks as self-sustaining businesses in the form of ‘Village Catalysts’. These people do appear to provide an important function in stimulating demand and providing some technical input to the projects. However, the new sources of finance (such as the World Bank financed ESD project) appear to require ‘certification’ of project designs and the quality of construction from people more formally qualified than the village catalyst. Either aid agencies and foreign NGOs will have to adapt their requirements of the people who arrange loan and subsidy finance or Village Catalysts will have to have their skills enhanced still further. The issue is one of balance between the cost of high quality intermediation and the reduction in risk that results from using more skilled people.

In Nepal equipment suppliers themselves perform some of the project development tasks. But here there would appear to be at least the potential for a conflict of interest and lack of independence in the advice given to the purchaser[53].

The scale and manner in which these ‘intermediation services’ will be performed will therefore depend on the form and scale of the money necessary to pay for them.

4.8 Specific Examples of Intermediation

The case studies show a number of interesting examples of the extent of intermediation.

4.8.1 Technological Intermediation

A great deal of the current success of micro hydro results from the early attempts to build technological capability with existing metal workshops in Nepal. The first oil crisis in 1973 stimulated the Nepalese government to look for alternative energy sources. A number of companies that had experience in building the traditional water wheel, graduated to adding

with a need and the people with the finance.

[53] Wolfgang Mostert, personal communication.

electricity generation onto improved water turbines[54]. By 1979 ADB/N had established their Appropriate Technology Units (ATU) to promote micro hydro and other technologies. Intermediate Technology Development Group (ITDG) became involved at this stage and worked with a number of the existing engineering companies to develop the technology. The capabilities of the manufactures was further enhances through a series of training programme starting in 1987 financed by ADB/N and ITDG. This experience was then transferred, and adapted, to other parts of the developing world[55].

4.8.2 Social Intermediation and Participative Approaches to the Management of Technical Change[56]

A major theme in the development of micro hydro technology has been the huge effort put in to 'Participative Approaches' to create, nurture and capacitate communities to build, own and operate micro hydro plant. These efforts trace their origins to the more general use of participatory development methodologies in the implementation of technology based projects. In Sri Lanka this process evolved into the development of Electricity Consumer Societies (ECS).

Box 4-1: ELECTRICITY CONSUMER SOCIETIES

The village hydro schemes of Sri Lanka are usually managed by an Electricity Consumer Society (ECS) or its legal and more recent equivalent, the Electricity Consumer Company (ECC), established for each project. These innovative mechanisms facilitate the participatory ownership and management of micro hydro schemes within village communities. Assistance in setting up the ECS was generally provided by an outside agency (a Non-Government Organisation, such as ITDG). A Society (ECS) was created in each village before it was able to request technical assistance to undertake a scheme. The ECS involves all potential beneficiaries of the scheme and becomes the operational and implementation conduit for the project. As the scheme moves into the operational phase it takes on a more managerial and regulatory role, although the structure and composition of the organisation remained the same.

The ECS became a pivotal institution within the village community. The office bearers would be selected at an annual general meeting, and sometimes include women. They would manage such issues as financial control, tariff setting, load regulation, agreeing electricity end-uses, taking action following breakdowns, and settling disputes arising from electricity usage within the community.

With the advent of bank finance for micro hydro the ECS had to be formalised into Electricity Consumer Companies in order to become a legal body, with a status of a small company. Any loan repayment thereby became the sole responsibility of the ECC.

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[54] Prominent among these were Balaju Yantra Shala (BYS) established in 1960 with the assistance of Swiss Development Corporation (SDC); Butwal Technical Institute (BTI) established with the assistance of United Mission to Nepal (UMN), National Structure (1963) Thapa Engineering Works at Butwal (1972); and The Engineering Company at Kathmandu (1973). In 1975 Butwal Engineering Works (BEW), a sister concern of BTI, designed and tested the first Pelton turbines. Nepal Yantra Shala (NYS) also started turbine manufacture in 1975. BEW fabricated the first Crossflow turbine in 1976. BYS fabricated the first turbine for generating 6 kW in 1978. In the same year Thapa Engineering Works built their first crossflow turbine, Kathmandu metal Industries (KMI), and National Structure and Engineering developed and installed the first Multi Purpose Power Unit (MPPU) to improve the traditional ghatta (water wheel).

[55] See for instance "*Micro Hydro Design Manual*" by Adam Harvey, Andy Brown, Priyantha Hettiarachi and Allen Inversin, IT Publications, London, 1993 228 pp, ISBN 1 85339 103 4.

[56] These issues are dealt with at greater length in "*Participative Planning Guidelines for Off-grid Electricity*" October 1999 (this material is available from IT Consultants www.itchltd.com). It provides evidence of a need for technical and managerial capacity being built at the project level at an early stage of project planning. Furthermore, unlike in other sectors, participation in micro hydro appears to need people with technical knowledge such as the "Village Catalysts" of Sri Lanka.

Similar village committees build and operate many of the hydro schemes examined in Nepal. They are responsible for the loans, set tariffs, and appoint the staff who operate the plant. In Peru rural people also had to organise themselves into 'pre-electrification committees' or other ad-hoc organisations in order to gain formal access to credit. This represents a major contribution that the IDB/ITDG revolving credit scheme made to building institutions with civil society in rural areas.

Community participation not only facilitates involvement in the design and operation of hydro plant, but it also enables costs to be reduced in three ways:

- it allows people to contribute their labour (or other communally owned asset such as land[57]) to the scheme. If people are under employed the opportunity cost of this labour can be close to zero, and its use need not involve the transfer of cash. This is often described as 'sweat equity' in that by contributing its labour the community gains a share in the ownership of the scheme;
- involvement of the whole community enables the richer elements (richer households, small mills and shop owners) to carry the bulk of the costs and thereby make a service available to the poorer people in the community. This can be done either through actual cross subsidy to the selling price (through a 'lifeline tariff') or by allowing them into the scheme at the marginal cost of including extra consumers rather than the average cost;
- increasing the number of people involved in a scheme can reduce the cost to everyone when micro hydro schemes exhibit economies of scale.

However, while involvement of the community is certainly a necessary condition for the success of some types of schemes, and can lower costs, the process itself is costly and time consuming. These costs are associated with understanding the needs of different users (for instance including both men and women), developing community motivation and 'ownership', and in training. Such processes may take a number of years and can add significantly to the costs of the NGO or other agency involved in project development[58]. If a single entrepreneur or a municipality is able to raise all the capital, it may well be that they can avoid the cost of community development and still have a successful micro hydro scheme.

4.8.3 Village Catalysts

In Sri Lanka another major element of the participative elements of village hydro programmes was the training of 'Village Catalysts' (sometimes known as 'barefoot' technologists). Ten catalysts have been trained. These were usually village level electricians or electrical repair technicians whose skills were upgraded by ITDG and their services re-orientated toward operational and maintenance support to village hydro schemes. They met the need to have 'trouble-shooting' capacity located near to the sites. Some catalysts are also capable of designing and manufacturing Pelton turbines up to 5 kW or so in capacity. In some areas there is sufficient demand to enable these catalysts to grow into entrepreneurs working independently. But despite their business-like approach they still perform services free of charge or at low cost to certain communities due to a sense of personal loyalty. Catalysts also promote hydro in other villages and are often the first point of contact for potential beneficiaries and respond to inquiries and demands of Provincial Councils. However, as

[57] The contribution of land is said to be crucial to the success of schemes in Sri Lanka where the state owns river banks, and would be unlikely to grant permission for individuals to use this land for their own profit.

[58] It has also been suggested that where community assets are used to build a hydro plant, such as the publicly 'shared assets' of the river bank or river water, there may be an insistence that 100% of the households are connected. This may affect costs, profitability and timing of the project. Diesel generating sets are said not to suffer from this "100% connection rate syndrome" (Wolfgang Mostert, personal communication).

suggested in Section 4.5, these catalysts cannot perform all the roles of project developer, as they are not yet perceived as sufficiently credible to financial institutions.

4.8.4 Marketing and the 'Creation' of Demand

The need to stimulate the demand for micro hydro through 'marketing' and publicising the existence of the necessary funding opportunities is a particularly important element of social intermediation in the examples cited in the Peru case study. This activity was an essential element in the success of the programme as relatively few people initially applied for support from the IDB funded, revolving Credit Fund. Even though interest rates and payment conditions seemed attractive when started, virtually no effective loans were made when the scheme was first set up. It was therefore necessary to adjust the strategy. Programmes that included visits of a team of promoters to the target towns to explain the details of the proposed funding scheme were established, including the participation in local and regional events, use of the radio and visits of students and others. Over a period of two years (1996 and 1997), nearly 40 visits were made, many of them to areas that involve many hours of travel from the nearest small town on a bridle path, the only means of access.

4.8.5 Lobbying

In most countries, technical competence in micro hydro has had to be complemented with the capacity to lobby for micro hydro development and the conditions that would at least give this technical option a fair hearing in the allocation of resources and in the formulation of policy. The most formal and successful of this advocacy function is probably the formation in 1990/1 of a Technical Assistance Committee (TAC) Sri Lanka which united a diverse set of individuals and organisations interested in micro hydro. Participants included representative of all sectors but, mainly NGO and the private sector. Staff from the utility were also active members. Its initial strategy was to incorporate micro hydro into the government's Rural Development plan but later facilitated greater co-ordination among all the actors working on micro hydro initiatives. More recently the TAC evolved into an 'Energy Forum' that lobbies for all decentralised and renewable energy options. Similar Forums have proved effective in Nepal and Zimbabwe and Peru.

4.9 Financial Intermediation and the Main Funding Mechanisms[59]

Micro hydro investments are costly and capital intensive. Therefore, access to appropriate forms of medium / long-term financing is critical. This means financial intermediation services in rural markets – the supply of debt and other financing to both suppliers of electricity (micro hydro owners) and to electricity users.

There are two broad channels for the flow of financing and related support to investor/owners and the ultimate energy end-users:

- the first channel is one of direct access by investors to finance the purchase to the technology and know-how and provide the necessary working capital;
- the second channel is indirect and supplies support through intermediaries who deliver technical and financial intermediation services to the investor or end-use consumer.

A number of business models employ versions of the indirect channel. For example, rather than a direct sale, an equipment supplier might provide an owner with a micro hydro turbine under a lease, or lease towards purchase ('hire purchase') arrangement. But the more common

[59] In addition to evidence provided by the country reports, this section draws heavily on a paper specially commissioned from Dr Russell deLucia.

of indirect approaches is in the form of a 'utility' or 'energy service company' (ESCO). In the most straight-forward of these, the owner not only sells electricity to the end-user but provides finance at least for the customer connection and perhaps end-use equipment (lights, TV etc). The investor/owner role is maintained for a long period or indefinitely.

The old-fashioned (but still existent) micro hydro grain mills are a form of ESCOs, the customer pays only for the energy-service (e.g. grain milled) and perhaps even pays in kind (a small fraction of the milled grain). In modern variants the customer pays only for energy (e.g. kWh), or energy-service (lighting or water being pumped).

Box 4-2 presents an indicative menu of the broad types of financing, structures and their sources. This draws on the body of experience on options that have been successfully used in OECD countries in supporting market penetration of small energy investments. Increasingly these options are now being used in a growing number of developing countries. While this menu is generally representative of the *direct* project financing approach, in many instances it is also indicative of the *indirect* financing approach.

Box 4-2: Indicative Menu of Financing Options (Types and Sources)

<u>Equity Financing</u> with financial resource mobilisation from:

- internal funds from the project sponsor / active investors / users;
- other active investors, such as venture capital funds, or investments by merchant banks;
- supplier (e.g. of equipment) as investor (part or all of equipment costs);
- passive investors through 'private placement' of equity financial-security instruments (e.g. shares certificate);
- passive investors through public (security-agency-regulated) placement/offering; and
- special categories of above where the investor has additional (non-financial) objectives, such as targeting environmental/green project or entity investments.

<u>Primary and Secondary (mezzanine*) Debt Financing</u> with financial resource mobilisation from:

- commercial and/or development bank and other Financial Institution providing working capital and term loans (limited recourse or balance sheet);
- complementary and/or alternative (often mezzanine) debt from 'active/directly involved' equity sources (categories 1.(a-c) above);
- export credit agency (ECA) source when equipment is imported;
- investment grade term-debt instrument (e.g. bonds) placed through limited offering to sources for which fiduciary and/or other constraints limit portfolio positions largely to such investment grade instruments;
- as in (d) but from a broader range of sources through a registered offering;
- 'junk' (non-investment grade) bonds (the more general case) placed to similar sources as in (d) and (e) but participation of sources for (d) constrained as noted; and
- analogy of 1.(f) for debt, sometimes as complementing equity position.

<u>Other Financing/Financial Support</u> – with financial resource mobilisation and/or support from:

- grants/contingent grants, cost shares sometimes for specific costs (e.g. pre-investment studies) or cost components from public agencies at federal, state or local level;
- depreciation and/or tax credits from federal, state or local authorities, which, in effect, lower the cost of debt and/or equity financing;
- lease financing from equipment suppliers, or through arrangements with Financial Institutions; and
- myriad guarantees, credit enhancements and/or other support usually from Development Finance Institutions' support by federal, state or local governments; to facilitate one or another of financing options above, or the creation of subcategory of one of these options such as 'tax-free' development, pollution control or other special bonds.

Source: modified from tables in previous deLucia and Associates, Inc. reports and papers.
Mezzanine finance is defined as "unsecured, higher yielding loans that are subordinate to banks and secured loans but rank above equity" (Encarta, 1998).

The most critical question in financial intermediation is who is responsible for transaction decisions and who bears what risks. If support from an International Financial Institution (IFI) is to work, experience suggests two very clear lessons. First, given the nature of transaction costs, this support can only be cost-effective if the Institution 'off-loads' most if not all transactional responsibilities to intermediaries. The smaller the scale of the investment transaction, the more necessary is this 'off-loading'. However the IFI must retain the responsibility of the appraisal and evaluation of the intermediaries, at least those at the highest level.

Secondly, the intermediaries must be responsible for the appraisal of the transaction (the investment and the credit worthiness of the borrower or end-user), the management of financial and associated risks, and of course, be responsible for ensuring transaction re-flows (the repayments).

A recent review of IFI operations in support of micro hydro and other small energy investments suggests three useful but sometimes overlapping representative categories of financial intermediaries[60]:

> *'Classical' Intermediation via Bank or Non-Bank Financial Institutions*. Nepal's Agricultural Development Bank of Nepal is perhaps the most well known example for financing micro hydro. ADB/N is a government owned bank which serves as an intermediary for the government's micro hydro (and other) programs; it has also been an intermediary for various International Financial Institutions. More recently the Sri Lanka Development Finance Corporation of Ceylon (DFCC) acts as one of the intermediaries for the funds provided by the World Bank under its Energy Services Delivery loan.
>
> *Intermediation via Other Non-Bank Specialised Financial Institutions.* Again citing an example with micro hydro experience, perhaps most well known of such institutions is IREDA – The Indian Renewable Energy Development Agency Ltd. IREDA was created in 1987 as a public limited company owned by the Central Government to promote renewable energy and to serve as a 'channel' for Government and International Financial Institution external funds. IREDA has supported a number of micro/mini/small hydro projects.
>
> *Intermediation via Non-Financial Institutions*. This is an envelope category including such entities as utilities, ESCOs, special purpose investment entities (e.g. development authorities, infrastructure funds) and others, including NGOs. An example of this is the revolving fund operated by ITDG Peru using funds sourced from the Inter American Development Bank.

The World Bank and other international development finance institutions are increasingly using a class of intermediaries which are financing funds or facilities whose management is the responsibility of a local bank or non-bank Financial Institution (or consortium). Such International Financial Institution operations, referred here as *Fund or Facility Operations*, are usually designed to provide a mechanism for the International Financial Institution to support

[60]Each of these categories is discussed, along with examples in the aforementioned report (De Lucia and Associates, Inc. July 1998) which is available from the World Bank.

private sector involvement in energy and other infrastructure development and to facilitate greater flow to these investments from the capital markets.

In Nepal where there is a new World Bank, 'Power Development Fund', it will be important to find a way of handling the transaction costs so that it will be giving extended support to viable micro hydro investments. Even when such operations exist and 'in principle' are open to supporting small-scale hydro, transaction costs lead the fund managers to avoid such investments.

Many NGOs have some experience in financial intermediation, for example operating savings and lending societies. While these loans are generally much smaller (and shorter term) than is required for investment in micro hydro, they may bring important knowledge of the financial strengths and weakness of certain individuals and groups (the NGOs' existing clients) who are potential borrowers for micro hydro schemes. Such NGOs might well 'graduate' to greater financial intermediation responsibilities, or amalgamate with larger financial intermediaries.

4.10 Current Financing Models for Micro Hydro

The case studies show that in practice many micro hydro plants are financed in the same way as houses are in developing countries. The funds come from a variety of sources, the investment is started before all the financing is in place, and construction takes place piecemeal when the necessary resources come available, often over a very long period. Schemes were generally implemented using grants or multilateral soft loans obtained by the project developer (usually an NGO). The exception in the schemes under review was in Nepal, where the ADB/N played a central role in financial intermediation.

This means that financial intermediation (or financial engineering) has crucial inputs that can be very costly. It also means that most of the existing financial mechanism targeted at micro hydro frequently do not provide sufficient funding, and certainly not from a single source.

In Peru, the ITDG/IDB revolving fund was created by the contribution from IDB with a capital of US$400,000, plus $120,000 for technical assistance. The repayment terms to the intermediary, ITDG, are set at a very low cost with repayments being made in local Peruvian currency . The funds for technical assistance are a grant and are not reimbursable. The scheme was designed for loans ranging from US$10,000 to $50,000 for each micro hydro power plant. The repayment was to be over (up to) five years, with an annual interest rate of 8% in U.S. currency (at this time the commercial current rate of interest in US dollars is at least 12 % per year).

However, the demand for credit from the revolving fund only became effective when additional funds were made available from other sources (regional government, poverty relief projects FONCODES[61]) and the rural consumers themselves. In Peru it was found that regional and sub-regional governments are more willing than the central government to support essentially decentralised schemes of this nature.

An interesting feature of the revolving funds is that ITDG hired an independent Credit Operator. This is a local entity (in the city of Cajamarca) that was contracted by ITDG to carry out independent assessments of the credit worthiness of the potential borrowers, to draw up and file the relevant credit agreement, disburse the loan and recover it. In this way, the project

[61] Compensation Fund for Development

developer, ITDG, was able to concentrate on the promotion, technical assistance and general supervision of the projects.

By the beginning of 1999 15 loans, totalling US$465,718, had been granted from the revolving loan. A total investment of $ 1,730,000 had been made for the installation of 15 micro hydro power plants in small towns in Cajamarca, Apurimac, Amazonas and Lambayeque. Repayment has been at a high level.

The following tables summarises this scheme:

Table 4-1: Sources of Finance from Micro Hydro Development in Peru

Source	**Amount**	**%**
ITDG/IDB Credit	$465,718	27
Regional and Sub-regional Government	$418,044	24
FONCODES	$328,475	19
Direct contribution of municipalities and small businesses	$242,730	14
Local contribution (population)	$47,330	3
Others (*)	$226,852	13
TOTAL	**$1,729,149**	**100**
*Including technical assistance and promotion funds provided by IDB (up to US$120 thousand) and other donors.		

Table 4-2: Types of Finance from Micro Hydro Development in Peru

Financial Component	**Use of Funds**	**% of total costs**
Loans	Civil works and electro-mechanical equipment	27%
Contribution by municipalities and small businesses	Pre-investment and other complementary expenses	14%
Grants	Technical assistance and promotion (13%) Civil works and distribution lines (43%)	56%
Contribution by local people	Manpower, materials	3%
TOTAL		**100%**

When a municipality is the owner of the micro hydro funds are sourced from both central government (transferred to municipalities), and from the local population through taxes. Indeed municipalities raise commercial loans against the guarantee of a ‘retention’, that if they do not service the debt, the payments will be deducted directly by central government from national tax revenues payable to the municipality.

In Sri Lanka, until the recent advent of the World Bank financed ESD project, funding for each project had come from a wide range of sources such as foreign donors, the government's poverty alleviation programs, local government bodies and charities such as the Rotary Club. Contributions in kind (sweat equity), mainly for the civil works, were a significant element in resource mobilisation. The cases showed that this source could be significant: at the Katepoloya scheme in Sri Lanka this was as high as 44%[62] of all costs, including labour . More generally in Sri Lanka beneficiaries provided some 30 % of the total project cost, when sweat equity is properly costed.

The World Bank is now the major contributor to village hydro finance in Sri Lanka by means of its Energy Services Delivery (ESD) project. The ESD provides a credit line to Participating Credit Institutions (PCIs) for medium and long-term credit for many renewable energy and demand side management projects. This includes village micro hydro and the rehabilitation of Tea Estate mini hydro sites. Finance for electricity end-uses at the community level is not specifically included, though it is implicitly recognised as a part of the project cost. However, existing micro credit institutions in rural areas (such as Sarvodaya and Sanasa) can provide both business development support services and micro-finance to new businesses based on electricity.

The Development Finance Corporation of Ceylon (DFCC) is the main operator of the World Bank programme and manages the loans to the Participating Credit Institutions. These loans are usually based on Average Weighted Deposit Rates (AWDR) in the commercial banking sector and PCI are free to on-lend at market rates. PCIs are free to adopt their own eligibility criteria with no specifications on debt to equity ratios as often the case with previous other World Bank loans. Nominal market interest rates usually vary but range between 15%-22% in current prices in local currency (inflation is currently about 7%). Rates are dependent on bank policies and individual project situations. The loan period is a maximum of 10 years including a maximum two-year grace period.

Borrowers repay ESD loans to the PCIs, and the PCIs make repayments in stages to the DFCC which in turn repays the money to the Government of Sri Lanka (GOSL) five years after initially drawing down the funds. The Government then repays the loan to the World Bank after a time lag.

The ESD provides grant funds for capacity building through training and through technical and generic market support for renewable energy services, by supporting educational promotion campaigns for off-grid energy technologies. This activity is subcontracted out to the Sri Lanka Business Development Centre (SLBDC).

Collateral in the Sri Lankan ESD programme is provided by the project's capital equipment and land leasehold rights. In such projects, land is often state or Crown land leased on a long-term basis and then mortgaged. In the event of defaulting, the site and land can be transferred and sold as a going concern.

As in the case of the Peruvian programme, ESD has required additional grant funds to get their programmes off the ground. These have been provided mainly through co-financing from the Global Environment Facility (GEF). These grant initiatives came into effect one year into project implementation following representation from banks, equipment dealers, and

[62] This figure seems quite high. However in schemes where a great deal of civil work is necessary, in kind contribution from beneficiaries might be significant.

consultants. In effect hard commercial funds from the private sector are 'leveraged' with softer public funds in order to cover the 'system overhead costs'.

The grant elements associated with ESD now includes:

- *Grant co-finance for loan applicants.* These are $400 for each kilowatt up to $20,000 for micro hydro plant (compared to $100 per 30 Watt Solar Home Systems – SHS);
- *Grants for Project Preparation*. These cover 95% of costs up to $9,000 for Micro Hydro (90% up to $6,500 for SHS);
- *A campaign to promote off-grid electricity*;
- *Grants to the PCU for Project Supervision.* Currently these are $1,200 for each micro hydro project ($50/SHS up to $600/sub project);
- *Grants for project supervision*. These grants enable consultants to verify the design of micro hydro projects and site specifications before loan disbursements.
- *Consumer education and protection facility.* This currently applies only to solar home systems and is a facility to investigate consumer complaints about dealers and to seek appropriate solutions.

It also appears that additional grant support is required for technical assistance to micro hydro development through ESD schemes and is currently being arranged through additional soft funds.

The ESD project started at the end of 1997 and has been in operation almost two years. To date it has approved around 13 grid connected and 7 off-grid micro hydro schemes.

In Nepal the Government requires commercial banks to invest 7 percent of their total deposits in the priority sectors. However the Government has to rely on the Agricultural Development Bank of Nepal (ADB/N) to administer its subsidy scheme for micro hydro. Formal financial institutions have been reluctant to provide rural credit. Commercial Banks (such as the Nepal Bank Limited and Rashtriya Banijya Bank) have a strong network of field offices and are able to provide credit in rural areas. The new joint venture banks have so far failed, however, to provide such services due to their inexperience in this sector. They mobilise funds through contractual arrangements with ADB/N.

Subsidies are provided for rural electrification programme through ADB/N. The terms of the subsidy have changed over the years, but currently they are available for systems up to 100 kW for water turbine and Peltric sets. The subsidy is available for the electrical components and varies from 75 percent for remote areas and 50 percent for other hill areas[63]. In effect this means that the subsidy is approximately 20-25% of the total investment cost. The micro hydro subsidy covers generators, load controllers, ballast heaters, earthing set, lighting arrestor, circuit breakers, drive system and transmission components including transmission cables, poles, insulators, stay wires and transformers. The subsidy on Peltric set is limited to capacities up to 5 kW. The limiting size of the penstock pipe for Peltric set is set at 100 m in length and 150 mm internal diameter High Density Polyethylene pipe. US $ 67/kW is provided for transmission poles in remote areas, US$75/kW is provided for other hilly areas. The subsidy for poles cannot exceed the cost of the turbine in the case of Peltric set. No subsidy is given specifically for household wiring, but a loan is provided to each household up to US $ 20.

[63] Information supplied by Devendra Prasad Adhhiari, Agricultural Development Bank.

Over the past 12 years ADBN has changed its interest rate for micro hydro development. As a result of price escalation, the higher cost of borrowing and the higher cost of lending, the rate has grown in stages from 11 percent to 19 percent. The current ADB/N's interest rates are high and appear to discourage borrowers.

Normally in Nepal some 20% of the total project cost must be found by the prospective 'owner' usually in the form of local labour. However in the case of Barpak, the local contribution (for the civil works) represented only 7% of the total costs.

Table 4-3: Summary of Current Financing Terms for Micro Hydro

	Primary Actors	**Funds**	**Financing Models**
Peru	ITDG	Inter American Development Bank, Local Government,	Revolving Fund Plus grants for project development.
Sri Lanka	Utility Energy Forum ITDG World Bank (recently)	Multiple sources	'Ad Hoc' multi donor, local grants, banks. World Bank ESD loans at 16% Grants.
Nepal	ADB/N loans and Government Subsidy Rural Energy Development Programme RADC	ABD/N and government UNDP funds, plus ADB/N loans, and contributions from District and Village Development Committees Government funds	Loans and Government subsidy.
Zimbabwe	ITDG	ITDG	Grants only
Mozambique	ITDG and KSM*	ITDG	Grants only, private contribution

*KSM (Kwasai Simukai) is a Mozambican NGO.

4.11 Collateral and Guarantees

Securing loans by means of collateral has frequently posed problems in micro hydro development, particularly in community-owned schemes. As with many project loans, the project's capital equipment and land leasehold rights are used as collateral. But in the case of micro hydro in Sri Lanka, land is often state or Crown land that is leased on a long-term lease and then mortgaged. In the event of defaulting, the site and land can be transferred to another and sold as a going concern. However, in practice it often takes time and considerable effort to establish title to the land, and particularly when the loan is to be raised by a limited liability company rather than the whole community.

Furthermore, the lack of technical expertise within financial institutions means that they are often unable to effectively monitor the construction and operation of the schemes that act as the collateral for the loans. This has also handicapped the financing mechanisms of the micro hydro sector in Sri Lanka.

In Peru the risks of loans has been reduced in a number of innovative ways. In one case (the 'Atahualpa' Farming Co-operative) the loan was guaranteed by 'hypothecating' rights to the income stream from the future sales of milk.

In the case of municipalities the loans are guaranteed by means of an 'intercept', whereby if the municipality defaults on the loan, the loan repayment is deducted at source from future transfers of resources from the central government to the municipality.

4.12 'Organisational Intermediation' and the 'Enabling Environment'

The success of micro hydro is clearly context specific. This specificity refers not only to the location of a particular site (is there enough water and a sufficiently 'concentrated' demand) at the micro level of analysis, but also at the specifics of the institutional arrangements at the macro level. The development of micro hydro has required one or more organisations to develop the national energy context – the 'enabling environment' - in ways that support (or are at least not hostile to) micro hydro development.

The characteristics of a favourable 'enabling environment' are relatively easy to list, but often requires huge effort to put in place. They are likely to include:

- A legal framework for contracts and effective means of their enforcement;
- A 'level playing field' in relation to the aid, taxes, subsidies and regulations that are provided to the main alternatives to hydro (grid electricity, fossil fuels, PV, etc.);
- A transparent policy framework (provided by the government or utility) for the development of energy options in general and the expansion of the electricity grid in particular (to reduce the risk of arbitrary or politically motivate expansion of the grid or other subsidised alternatives, such as PV);
- Capital supply systems (capital markets) able to supply adequate financial resources (grants, soft and hard loans, equity);
- Reasonable arrangements for collateral;
- Government support to training, R and D, and 'public goods' such as information about the resource base;
- Systems for the competitive supply of technical and business support that is suited to small scale enterprise in rural areas;
- Adequate access to competitively priced micro hydro technology and related knowledge;
- Sufficient competitive suppliers with the technical capacity to select, design, install, test, operate, and maintain the plant, equipment and civil works required by micro hydro;
- Systems for defining and enforcing appropriate technical standards; and
- Transparent and fair mechanisms for the sale of micro hydro electricity to the grid.

The following sections describe some of the features of the 'enabling' or indeed 'disabling' environment that is confronting the expansion of micro hydro in practice. Much of the pre-existing policy environment was not designed specifically for micro hydro, and whilst it may have not been actively discriminated against, a large amount of complaints stem from the fact that governments forget about it as a viable option. Many of the negative effects are likely to be unplanned. For instance governments subsidise grid electricity explicitly and implicitly for a variety of reasons, but are unwilling or unable to extend the same concessions to micro hydro. Diesel engines are imported free of duty but not the technology associated with micro hydro, and so on.

But those that seek to ‘regulate’ the development of the micro hydro sector need to keep in mind that many of the regulations governing rural development merely provide another mechanism by which those in power can exploit the weak by demanding bribes and other kinds of ‘rent seeking behaviour’.

4.13 The Regulatory Framework

The ad hoc nature of the regulatory framework governing micro hydro is illustrated by the case of Sri Lanka. The regulatory framework is unclear and is characterised by a multiplicity of institutions at various levels. The required approvals are illustrated in the following table:

Table 4-5: Approval Required for Micro Hydro Installations in Sri Lanka

Environmental approval or Licence	Institution
Letter of Support on general project viability & willingness to purchase electricity (for Grid connected sites) to facilitate other agency approvals	Ceylon Electricity Board (CEB)
Use of water resources, road development, construction of buildings & canals	Divisional Secretary / Irrigation Engineer etc. or, Pradeshi Sabha
Letter on site observations & recommendations on environmental impacts based on Environmental Impact Assessment Questionnaire for Micro Hydro (1997)	Pradeshi Sabha or Divisional Secretariat to The Central Environmental Authority (CEA)
Electricity Licence to generate & sell electricity	Chief Electrical Inspector, Ministry of Irrigation & Power
Investment & Tax concession for large infrastructure projects	Board of Investments
Title or lease or permission on land use	Land owner or Divisional Secretary

In Sri Lanka, the Electricity Utility (CEB) limits its regulatory role to determining the standards for connecting private power generation to the national grid. Otherwise there is very limited regulation in relation to off grid micro hydro. That regulation that does impinge on micro hydro relates to use of natural resources such as lands, water and forestry resources. Land use is dependent on property rights where the use of public lands requires local government (at the level of the Pradeshi Sabha). The same approval is required with use of waterways. Regulation of waterways feeding irrigation channels come under the purview of a separate entity, the Irrigation Department.

When transmission lines within a village cross public land they do so without any permission or approvals being sought and with no formalities encountered. If a micro hydro site requires significant use of public land however, either by a private developer or rural community, government lease procedures may apply and approvals obtained from both the Minister of Lands and the President. Private land is frequently used for the construction of micro hydro powerhouse buildings with little regulation except for verbal agreements with the landowner who is almost always a beneficiary in the project.

In Sri Lanka, non-state actors have often stepped in to fill gaps left within the state structure. Developments in micro hydro tend to ‘fall out’ of the plans and procedures of the formal electricity generation and distribution systems. While there are specific standards for construction and installation of all electricity installations in Sri Lanka, they are not strictly enforced in the village hydro sector, and were not specifically designed for the village energy use. Construction and safety standards depend entirely on the people involved with the project and the requirements of the institutions that provide the funds. In order to tackle this problem the World Bank financed Energy Services Delivery (ESD) programme has commissioned a study to establish appropriate standards in village-hydro electricity distribution systems[64].

It is likely that environmental regulation will become an important feature of the regulations governing micro hydro in Sri Lanka. The Central Environmental Authority (CEA) the main body overseeing environmental policy and regulatory processes developed an Environmental Impact Assessment Questionnaire for Micro Hydro in 1997. This has many shortcomings, not least that it does not distinguish between different scales of micro hydro plant, adding a considerable burden to very small systems[65]. Implementation is variable, as local government capacity on environmental issues and regulations is generally weak and unclear. Some Provincial Councils do have Environmental Officers but they are often marginalized in the institutional process and have little authority.

The situation regarding private power producers in Sri Lanka is still evolving. Private Power Producers can only legally sell power to the Ceylon Electricity Board. However there can be exceptions if specific approval is given, although this permission is rare. Electricity Consumer Societies (in villages) avoid this problem by selling power only to their members (and technically they pay a ‘membership fee’ rather than a ‘fee for electricity’).

In Peru the regulatory environment also appears to by-pass micro hydro. What exists is a regulatory framework, largely related to the allocation of concessions aimed at promoting private investment in generating and distributing electricity. The legislation essentially leaves it to ‘market forces’ to select the technologies to be used to generate power and distribute electricity to areas not covered by the electricity grid. In practice, however, the incentive structure demonstrates a clear preference to support grid based electrification.

As far as the public sector is concerned, the institutional framework for rural electrification consists of The Ministry of Energy and Mines. Through its Executive Projects Directorate (DEP) it is responsible for expanding the electrical frontier throughout the country. A number of other government institutions are involved, but their role is limited to financing schemes in rural areas. With the restructuring of the power sector since 1990, several municipalities will be handing over the electricity services to concession companies, given the legal, financial and economic guarantees that make it attractive.

[64] These specifications are based on relevant national and international standards. They specify separate standards for systems under 5 kW, between 5 to 15 kW and, systems between 15kW to 50kW (Village Hydro Distribution System Specifications for the ESD Project, March 1999 Draft version, Intermediate Technology Sri Lanka). These specifications have been in use since June 1999.

[65] Currently even sites 2-3 kW in capacity have to go through the process of filling in these environmental clearance forms and getting the necessary approvals from the CEA and Provincial Councils.

Experience with Peru's revolving fund shows that the criteria generally used in larger construction works in urban areas cannot be applied to micro hydro installations in rural areas. Technical standards and the costs of equipment, and machinery must be modified for small projects of this nature to ensure that they are appropriate to their rural surroundings.

In Nepal the Ministry of Water Resources (MOWR) is directly responsible for electricity and supervises the Nepal Electricity (NEA) and Electricity Development Centre (EDC). EDC was established in 1993 under MOWR to promote private sector participation and license both NEA and private power producers on behalf of MOWR. The EDC grants licenses for independent generation and sale to NEA and assists Independent Power Producers through a range of activities including site identification for small and medium scale projects. EDC supports the Electricity Tariff Commission (ETC) which was set up in 1993 as an independent body to regulate electricity tariffs and ultimately to arrange for the power sales between NEA and private power producers.

The Ministry of Science and Technology (MST) has a mandate to promote national science and technology and oversees the Alternative Energy Promotion Centre (AEPC). The mandate of AEPC is to promote renewal energy technologies to meet the needs in rural areas of Nepal, but as a technology based organisation it does not become involved in creating appropriate frameworks for rural tariffs or the organisational frameworks necessary for the creation of decentralised power companies.

The Nepal Electricity Authority (NEA) is a semi-autonomous institution responsible for the generation and supply of energy. However neither NEA nor any other government authority appears to be responsible for isolated grids. NEA has been able to cover 15 percent of the total population through expansions from the national grid. The service provided by NEA is largely been limited to urban and semi-urban areas. Micro hydro development is governed by two acts passed in 1992: the Water Resources Act; and the Hydropower Development Policy Act. Licenses are not required for running water mills, as they are considered a cottage industry. The Electricity Act of 1993 opened up investment opportunities in the electricity sector from national, foreign or joint venture companies and made provision for concessional loans to generate and distribute electricity. The policy has also waived the license fee for surveys, generation, transmission and distribution and stipulated that the Nepal Electricity Authority (NEA) will provide compensation to existing private owners and operators of micro hydro plant if the grid is extended to their customer area.

A particular void in appropriate institutional arrangements concerns the standardisation of the turbine-related components and quality assurance of the technical performance of the turbines. The Nepal Bureau of Standard could take a lead role in this.

4.14 The Special Case of Mozambique and Zimbabwe as New Entrants Into The Micro Hydro Sector

Zimbabwe and Mozambique were included in the case studies to illustrate programmes at the earliest stages of development. In both countries the first micro hydro power plants were installed in the 1930s. However, interest in this technology faded with the coming of grid electricity and the hope that this would be extended to the remotest users. Both economies have suffered civil war and although Mozambique seemed to be faring better than Zimbabwe in terms of recent economic growth (at least before the devastating floods in 2000), every sector of each economy has to compete for the available but inadequate resources. There is therefore pressure to use the available resources (such as renewable energy resources) more efficiently and to direct them towards sustainable options in trying to achieve economic growth.

In Zimbabwe the energy sector is going through important change. New policies and strategies are being formulated to address needs, meet national objectives, regional and international obligations. There is also a renewed interest in decentralised (often renewable) energy resources. Most investment in the energy sector goes to the standard energy options of liquid fuels, coal and grid electricity, but this investment serves only between 10%-20% of the population while the remainder, mainly in the rural areas, do not have access to modern forms of energy.

In both countries the utilities see the expansion of decentralised and small scale energy options as against their commercial objectives. There has been more activity and interest in small scale renewables in Zimbabwe than in Mozambique. In Zimbabwe a range of stakeholders including foreign donors have begun to develop the renewable energy sub-sector, spurred by such processes as the World Solar Summit Process, and the attentions of the Global Environment Fund.

Zimbabwe has accumulated some experience on renewable energy technologies among them: wind; solar PV; solar water heaters; solar dryers; micro hydro; biogas; and, other biomass technologies. However, in Mozambique very few elements of the 'enabling environment' are yet in place at the national level for decentralised energy supply to thrive. The government's ability to formulate energy policy is professionally weak, and there is a clear need to systematically review policies relating to energy pricing in general and electricity tariffs in particular. Policies for supporting and financing small scale renewables also need to become more consistent. Local financing mechanisms are totally absent, and most of the initiatives in the small renewables sub-sector have relied on external donor funding.

In both countries the strategy has been to demonstrate what micro hydro technology can do, using this experience both to gain familiarity with the technologies and to lobby government, and other agencies, about the role of decentralised (largely renewable) energy technologies.

In Zimbabwe a few plants providing milling services and electricity to remote rural areas have demonstrated the potential of this technology. Some of the locations have had electricity more than thirty years ahead of grid electrification, and at a significantly lower cost than competing options such as diesel engine generator sets or PVs.

Two micro hydro plants were examined in detail in each country. In Zimbabwe they were located at Nyafaru and Svinurai, and are both community-owned and benefiting from local subsidies. In Mozambique the two plants selected were at Elias and Chitofu. In contrast these are both privately owned schemes and were grant financed.

A conventional financial analysis shows schemes intended to produce mechanical power might be financially profitable whereas there is no return for Nyafaru which main purpose is electricity generation for domestic end uses. This is mainly due to the high capital costs of the installation, low tariffs and low plant utilisation, usually at less than 50% capacity. In all the schemes, social objectives dominate the setting of tariffs, and no allowance was made for depreciation in tariffs. Such schemes cannot be used to model loan finance unless their utilisation can be increased and the tariffs raised.

In the Zimbabwe cases each type of consumer pays a different tariff, with households paying less than more commercial enterprises. Steps are being taken at both Svinurai and Nyafaru schemes to improve the utilisation of the plant and then increase the tariffs. At Svinurai a generator awaits commissioning, due to extend power to commercial units at the farm. At Nyafaru there is a proposal to move down from around 5 Amp miniature circuit breaker (MCB) to 3.5 Amp MCB, in order to increase the number of users but maintain the same tariff at least in the short term.

In both cases the communities and entrepreneurs do not look at the hydro plants as stand-alone business units, but as part of bigger enterprises. All four plants show cross subsidies at the local level. However the movement and cost of finance, labour and materials at the local level are not easy to track. This could be best tackled by building up the capacity to account for such movements and costs at the local level. Local capacity to account for costs and income should complement the capacity to operate and manage management such small enterprises. In the case of Svinurai this is already happening through the efforts of various stakeholders assisting in building up the management capacity of the co-operative.

5

BEST PRACTICES: THE LESSONS LEARNED

5.1 The Critical Factors

- Micro hydro programmes and projects need clear objectives. Is the project or programme:
    - An investment in social infrastructure (that will be considered in the same way as a training scheme, a safe water supply, school, a health programme?);
    - A programme to sell as many micro hydro schemes as possible (regardless on the users' needs); and
    - To create small profit making enterprises that are financially self-sustaining.
- Financially self-sustaining projects have cash generating (usually day time) end-uses to produce cash flow and increase the use of the plant (load factor). Lighting-only systems will have the greatest difficulty in achieving financial sustainability.
- Subsidies are likely to be necessary if micro hydro schemes are to substantially improve the access of poor people to electricity.
- The cost of micro hydro plants is dependent on location and standards although effective management can contain this.
- The form of ownership of micro hydro plant is probably less important to success than creating an effective business-like style of management.
- Selecting and acquiring micro hydro technology that is appropriate to the location and task remains a necessary condition for success (wrongly sized plant and inappropriate standards remain a constant threat).

5.2 Best Practice and Profitable End-uses

- It is easier to make a profitable micro hydro plant socially beneficial than to make a socially beneficial plant profitable
- Profitable end-uses are difficult to develop because of the limited size of the local market and the general difficulty of small and micro enterprise development in remote locations.
- Financial institutions willing to finance micro hydro should consider funding associated end-use investments in order to build profitable load.
- It may well be that micro hydro should be promoted for its role in securing livelihoods, or developing small enterprises, rather than as an ‘energy programme’.
- The choice of end-use can affect those who benefit from micro hydro and will therefore effect the poverty and gender impacts, even if not all the community has direct access to the energy.

5.3 Best practice and Tariff Setting

- The financial performance of all micro hydro plant could be improved if the average tariff was kept in line with local inflation.
- Life line tariffs under which the richer consumers cross subsidise households that cannot pay will spread the poverty reducing benefits of micro hydro - as long as the total revenue is adequate.
- While there is clear evidence that demand is sensitive to the tariff charged (many potential users would be excluded by full cost covering tariffs in many locations), there is also evidence that the ability of some people to pay is higher than originally thought.

5.4 Best Practice for Governments

- Governments need to assign clear responsibilities for micro hydro development and the development of the necessary ‘enabling environment’. Best Practice suggests that this would ideally be part of assigning more general responsibilities for the provision of de-centralised energy services to rural (or marginalized).
- Governments need to treat all energy supply options equally (‘offer the full menu of options’) and to favour what best meets the needs of the consumer in different locations.
- Governments need to ensure fair competition between competing supply options and provide equal access to aid and other concessional funds, subsidies, tax breaks and support.
- Plans for the expansion of the electricity grid should be rule based, and in the public domain to reduce the uncertainty about when the grid will reach a particular location. Clear rules should be published regarding the actions the grid supplier must make to compensate micro hydro owners when the grid arrives (either to buy out the plant at written down costs or to buy the hydro electricity produced).
- While government finance tends to favour large scale energy investments (in say power or fossil fuels), micro hydro has the opportunity of utilising local capital (even the creation of capital through direct labour to build civil works) and it is part of the new trend towards ‘distributed’ power with much reduced costs of transmission.

5.5 Best Practice for Regulation

- Regulation should aim to produce a structure of incentives that result in the needs of consumers being met most cost-effectively. It should be technologically neutral, and at costs that are in keeping with the scale of the investment and the ability of the various parties to pay.
- Regulation should be transparent, stable and free from arbitrary political interference so as to foster competition between suppliers of technology, services and finance.
- Regulation should set standards that are appropriate to the project cost and the ability of the various actors to pay.
- Quality and safety standards should be enforced to prevent the users being exploited by shoddy equipment and installations.
- Regulations should be designed so that they do not merely increase the opportunities for “rent seeking behaviour" of officials.
- Regulations should be set so that: independent power producers can supply power to the grid at ‘realistic’ prices; and connection standards are appropriate for the power to be sold. Rules should be transparent and stable.

5.6 Best Practice in Financing

- Best practice suggests that the expansion of micro hydro will continue to need both 'soft funds' and funds at commercial rates, particularly if micro hydro is to meet the needs of people with low money incomes.
- Funding will be needed to cover capital costs, technical assistance and social/organisational 'intermediation'.
- Micro hydro development will need to leverage funds from many sources including those for small enterprise development, livelihood development, technical assistance social infrastructure, as well as the more usual energy and environment sources.
- Micro hydro will need to widen the menu of financing options for acquiring both debt and equity, including leasing, novel forms of debt guarantee, and novel forms of collateral (e.g. in Peru the hypothecation of the cash flow from energy end-use, and municipal loans guaranteed by 'intercept' on revenues from Central government).
- Loan conditions should be simplified, and collateral conditions modified to suit local conditions for asset (land, equipment) ownership.
- Some financial institutions are likely to require training to understand the special needs and risks of micro hydro, or to build on analogous experience in other forms of rural investment.

5.7 Best Practice for Smarter Subsidies

- Subsidies should be designed to achieve clearly stated objectives and should develop rather than destroy markets.
- A particular problem with current subsidies provided by bilateral donors is that they have a tendency to 'pollute the well' – that is, they use their subsidies to spoil the market for others.
- Smart subsidies should:
  - follow pre-established rules that are clear, and transparent to all parties;
  - focus on increasing access by lowering the initial costs (technical advice, capital investment) rather than lowering the operating costs;
  - Provide strong cost minimisation incentives such as retaining the commercial orientation to reduce costs;
  - remain technologically neutral;
  - cover all aspects of the project including end-use investments, particularly to encourage pro-poor end-uses; and
  - use 'cross subsidies' within the project to pay for life line tariffs and other 'pro-poor' recurrent cost subsidies (e.g. enable transfer from richer sections of the community, and commercial users to marginal connections).

5.8 Best Practice for Donors

- Build programmes on a thorough understanding of what has already been tried before in the country and elsewhere.
- Adopt funding strategies that enhance (rather than duplicate or destroy) local capabilities including organisations, regulatory frameworks, and technical capacities.
- Maintain the 'full menu' of options, so as to give micro hydro the same chances for funding as other decentralised energy supply options.
- Ensure funds build markets rather than destroy them - apply the principles of 'smarter subsidies'

- Ensure funds are available for both micro hydro and associated end-uses. Give particular attention to the encouragement of pro-poor end-uses (and the views of women as major players in traditional energy systems).
- Ensure funds are available for all aspects of project development.
- Use soft funds to leverage access to large flows of more conventional loan and equity finance.
- Be transparent to make others aware of what you are doing and try to harmonise activities with other donors, partners, equipment suppliers, contractors, and government programmes.

5.9 Best Practice for Project Developers

- Project developers who have the skill and tenacity to put all the elements of a micro hydro plant together are crucial to the success of programmes, and are likely to be the main constraint to programme expansion, particularly if their costs cannot be covered by grants
- Successful micro hydro programmes will need to be sufficiently large to produce sufficient work for the project developers and to achieve economies of scale in the supply of such services - such as where there are a number of plant in the same area allowing for costs of site visits to be shared by a number of installations.
- Financial institutions and regulatory agencies need to strike a balance between their need for project developers they regard as credible (speaking English with formal qualifications in engineering and accountancy) and their cost. Best practice probably requires lower cost project developers with specific practical experience with micro hydro and the communities that use them.
- The costs of ‘intermediation’ in project development should be recorded, and attempts made to cover them directly with grant funding.
- Efforts should be made to estimate the realistic size of the market for micro hydro, taking into account, costs, alternatives, and the likely availability of finance, so as to determine whether the process of project development can be put on a more sustainable financial basis (including grants). Additionally the scale of project development capabilities should be increased sufficiently so as to reduce unit costs by capturing the economies of scale.
- Technical assistance services should be separated from credit functions to ensure that sound judgements are made about the financial viability of each project (with or without subsidies) and credit worthiness of project owners.
- Consideration should be given to productive end-uses from the outset, and treat micro hydro investment as a small enterprise (regardless of actual ownership structure).
- Endeavour to create a business like management structure, even if co-operative or other forms of joint ownership are used.
- Attempt to institute rules for tariff setting and for inflation adjustments that are technical and routine rather than arbitrary and politicised (e.g. link the price of electricity to some other freely traded commodity - such as a staple crop, kerosene, or candles).
- Successful programmes include activities that stimulate demand for hydro and the financial and other support activities that are available.
- Successful programmes include activities that lobby for changes in the ‘enabling environment’ created by government, financial institutions and donors. These are

probably most effective when operating as an 'Energy Forum' combining the interests of all people interested in rural, 'alternative', or decentralised energy options.

- Project development would benefit from technical catalysts who can work in close proximity to villagers at relatively low cost.

5.10 Best Practice for Capacity Building

- There would appear to be no short cuts in developing local capacities. The process takes a long time and is costly, but without such capacities micro hydro programmes cannot succeed.
- Local capacities to build micro hydro plants locally appear to substantially reduce costs
- Local capacities to manage, operate and maintain micro hydro plants are a necessary condition for success and resources will need to be devoted to building this capacity.

5.11 Best Practice for Management of Micro Hydro Plant

- Regardless of ownership structure, it would appear that the successful management of micro hydro plants requires a 'corporate structure' that minimises political interference (e.g. from municipal authorities or powerful community members) by providing clear delegated authority to a management to achieve clearly stated objectives related to profitability, coverage, and the quality of the service to be provided.

ANNEX

SUMMARY OF THE CASE STUDIES

1. SRI LANKA

1.1 The Sample

There are approximately 130 MHP plants[66] currently in operation in Sri Lanka. Most are less than 100 kW in capacity. The sample of projects were drawn from a total of about 70[67] village micro hydro plants and 13 estate MHP sites. There is estimated to be 60 estate MHP plants in operation. This number has been obtained from various information sources[68] as there are no database records for this category of MHP.

Although MH development dates back to the tea plantations in the pre-independence British colonial era, the availability of data is extremely limited. The recent resurgence of interest in MH in the 1980's has generated a great deal of experience of improved technology, but systematic data remains scarce.

Study criteria led to purposive selection of sites for in-depth review and assessment. The selected sites and the criteria are given in the table below:

Table A-1: Selected Sites and Criteria, Sri Lanka

Site Name	District	Date	Ownership	Capacity	Source of Finance	End-use
Pathavita 2	Matara	1997	Community	10 kW	Loan + Comm.	Ironing centre
Kandaloya	Kegalle	1998	Community	10 kW	Loan + Grant / Comm.	Fridge & ice-making
Katepola	Ratnapura	1995	ECS*	24 kW	Grant + Comm.	Rice mill
Seetha Eliya	Matara	1985	Private	60 kW	Private + Bank + Grant	Tea factory + lighting

*Electricity Consumer Society

Four micro hydro sites representing different financing arrangements and end-uses were selected to carry out the sample analysis on financial viability of such projects. Three of the sites have been established only during the last two to three years while the other has been in operation for 14 years. At the first three sites energy sales to individual households are not metered; each household pays a fixed monthly fee with the understanding that the restriction on power use is adhered to.

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[66] Details of these sites are available through Intermediate Technology Development Group's (ITDG) Sri Lanka database on MH (referred to as ITSL). These are listed briefly in the annex.

[67] This number is derived from ITDG's Sri Lanka database, January 1999. Figures change periodically as more MH sites enter the pipeline or are implemented and incorporated accordingly into the database. See annex 1 for excerpts from this database.

[68] For more details see Country Report for Sri Lanka, December 1999.

Figure A-1: Map showing the locations of the case study sites in Sri Lanka

1.2 Case Study Details

1.2.1 Site 1: Katepola

Katepola, a community-based village hydro project, is predominately financed by grants, with equity contributions made by villagers in the form of labour and finance. No commercial loans have been used.

Village Overview

Katepola is a village with a population of 350 families situated in Ayagama secretarial division in the Ratnapura District. Inhabitants of Katepola are generally in the low-income category, earning their living from rubber, cinnamon and paddy cultivation, or by employment at the Dumbara Estate. The neighbouring village of Katepola, Umangedara, is home to the first village hydro scheme established by ITDG Sri Lanka.

Project Overview

The Katepola village hydro plant using the flow of Thundola stream, has a capacity of 25 kW. It consists of a stand-alone synchronous generator with an Electronic Load Controller (ELC), supplying power to 106 houses and a rice-mill.

A significant part of the project cost was born by the ECS, whilst important contributions in the areas of technical assistance and financial co-ordination were made by ITDG.

Table A-2: Katepoloya Scheme Profile (US$1998)

Capacity of MHP:	25 kW
Start date:	1994
Total Capital cost: of which Electromechanical: Civil: Other* (incl transp/distrib)	US$54,529 US$21,664 (39.7 %) US$23,874 (43.8 %) US$8,991 (16.5 %)
Grant:	US$34,654
Connection charge per HH:	US$64 in 1995 then US$174 from 1997
HH allocation in Watts:	200 W
Hours of HH usage per day:	5 hours
Cost per installed kW:	US$2,181

Other costs: mainly transport and distribution for electricity generation schemes.

The management, financial control and load regulation is carried out by the Electricity Consumer Society (ECS) established at the conceptual stages of the project. This is a society formed by the villagers consuming the electrical power delivered by the village hydro plant. The office bearers, selected at an annual general meeting are responsible for the management, which includes taking necessary action for breakdowns and any other disputes arising from electricity usage within the community.

This village hydro scheme provides electricity to 106 houses; each supplied with 200 Watts of power at a monthly charge of US$1.43 (Rs 100 in 1999) per household. The scheme also powers a rice mill, which is supported through grant funding from ITDG and operated solely during the daytime. The mill is supplied with electricity free of charge while the income from rice milling is credited to the ECS after paying the operator.

1.2.2 Site 2: Kandal Oya

This is a community-based project, predominately financed through the Energy Services Delivery (ESD) scheme, with equity contributions made by villagers in the form of labour and finance. There is a great diversity of small-scale end-uses at this site.

Village Overview

Kandal Oya is a remote rural village located approximately 23 km away from Yatiyantota, in Yatiyantota divisional secretariat of Ratnapura District. The community is largely agricultural, with a reasonable household income. There is a high demand for electricity for lighting and other household requirements.

Project Overview

The project consists of a 10 kW stand-alone induction generator with an induction generator controller (IGC) and presently serves about 88 households. This village hydro scheme has been financed through the World Bank's ESD project. The scheme is owned by a limited liability company formed by the membership of Electricity

Consumer Society, consisting of connected households. This is a legal entity set up to facilitate the management and to support long-term financing and repayment.

Table A-3: Kandal Oya Scheme Profile (US$1998)

Capacity of MHP:	10 kW
Start date:	1997
Total Capital cost: of which Electromechanical: Civil Other (inclu trans/dist):	US$31,148 US$6,152 (19.8%) US$9,822 (31.5%) US$15,174 (48.7 %)
Loan interest:	0.16%
Loan amount:	US$8274
Grant component of the loan:	US$4468
Repayment period:	5 years
HH allocation in Watts:	100 W
Hours of HH usage per day:	5 hours
Tariff per HH/month:	US$3.85
Cost per installed kW:	US$3,115

1.2.3 Site 3: Pathawita 2

This is a community-based project, funded through the ESD project, with equity contributions from villagers in the form of labour and money.

Village Overview

Pathawita is a remote village situated in the Matara District of the Southern Province, about 200 km from Colombo. The village, separated into two major sections by a mountain, consists of around 200 houses spread over a large area of land. This dispersal of housing has created major barriers in supplying electricity to the whole village economically, and with an acceptable voltage profile. The closest access to the village is through Kotapola and off Beralapanathara in Kotapola Divisional secretariat.

Project Overview

The site identified for the establishment of a hydro plant had a continuous potential of 10 kW. With the financial assistance of the Rotary Club of Colombo-West, an induction generator (capacity 5.5 kW) and an induction generator controller made in China were imported and installed. At the initial stage, the project could supply power to only 66 houses.

Table A-4: Pathawiata Scheme Profile (US$1998)

Capacity of MHP:	10 kW
Start date:	March 1997
Total costs: of which Electromechanical: Civil work: Other (inc.trans/dist)	US$22,031 12,811 (58.1 %) 5,926 (26.1%) 3,294 (15 %)
Loan interest:	16%
Loan amount:	US$8,274
Grant Component of the Loan:	US$2,797

Repayment period:	8 years
HH allocation in Watts:	100 W
Hours of HH usage per day:	5
Tariff /HH/month:	US$2
Cost per installed kW:	US$2,203

A second stage of the project was initiated in a bid to harness the total hydro potential. Commissioned in November 1997, a new turbine generator with a capacity of 10 kW was installed in the place of the previous turbine and generator. This new scheme supplies power to 103 houses in the village.

The second stage of the project was funded through the World Bank's ESD programme. ITDG co-ordinated the finances and any technical contributions required, arranging technical services through the consultancy firm Consultancy and Professional Services (CAPS).

The loan was granted to a company formed by the village electricity consumers' society (ECS). Along with the loan of US$8,274 (Rs. 500,000 in 1997), the company received a grant of US$2,797 (Rs. 169,000 in 1997).

The company charges US$2 (Rs. 140) per month per household, allocating 100 Watts per household. The operator of the powerhouse receives US$14.3 (Rs. 1,000) monthly. Presently the company is facing a severe threat to its existence with the national grid penetrating into the areas supplied by the hydro scheme. The immediate problem of losing its consumer base and in attracting new customers may result in difficulties paying back the 8 year loan under the ESD program.

1.2.4 Site 4: Seetha Eliya.

Village Overview

This is a private project, with equity and commercial loan financing. Energy is used to supply the operating requirements of a tea factory. Seetha Eliya micro hydro plant is situated in Kandilpana, Deniyaya in the Matara District. This is one of the few plants initiated, constructed and managed by the estate sector in the country. The plant has a capacity of 60 kW, which falls in a range clearly above the average capacity of village hydro plants of Sri Lanka.

Table A-5: Seetha Eliya Scheme Profile (US$1998)

Capacity of MHP:	60 kW
Start date:	1985
Total costs:	US$225,665
Loan interest:	26%
Loan amount:	US$98,544
Grant Component of the Loan:	0
Repayment period:	10 years
End-use:	Electricity supply for a tea factory
Cost per installed kW:	US$3,761

Project Overview

This plant was constructed by Seetha Eliya Tea Factory with the main intention of supplying power to the operations of the factory, including lighting. The total cost has been borne by a loan and an equity investment by the tea factory.

The plant was initiated with the aim of using streams in the land of the Seetha Eliya Tea Estate, thus relieving the burden of costly electricity bills. Construction of the plant started in 1983 and the plant was commissioned in 1985. Initially an induction generator was used; later generation was transferred to a synchronous generator. Unlike other micro hydro schemes, there was no grant component associated with the loan. Project financing was done through a commercial loan at an interest of 26%. The management, financial control and load regulation is carried out by the factory itself. There is no separate management body for the plant and no separate income stream, apart from the avoided cost of grid electricity.

A major difficulty faced in the process of construction was getting the required approval from local authorities. Most of the land within the tea estate has been used for the project apart from around 0.5 hectares of land, donated by the owner of the estate to outsiders in return for using their land for the pipelines.

1.3 Financial and Economic Analysis

The key results and findings are presented in Table 6[69]. Two sets of scenario were considered.

Table A-6: Internal Rates of Return and Return on Capital Invested (IRRci) After Financing (%)

	Katepola		Kandaloya		Pathewita 2		Seetha Eliya	
	cur	const	cur	const	cur	const	cur	const
IRRci	14.7	8	15	9.3	32	16.3	24	12.4
IRR	Negative		10	6.9	6	3.1	24	12.4

The community-based projects with financing from the ESD programme (Kandaloya and Pathewita) have an IRR in constant dollars of around 7% and 3%, while the scheme with total grant funding (Katepola) has a very low or negative IRR. The privately-owned project (Seethe Eliya) has a very high IRR, 24% and 12.4% respectively in current and constant dollars.

The return on capital invested (IRRci) in ESD project-based schemes is around 9% and 16% in constant dollars. The present bank interest rates for cash deposits, and interest rates for treasury bills vary between 7% to 12% depending on the type of deposit. Considering these rates and the IRRci, it is apparent that projects financed under the conditions similar to those of the ESD project can be justified not only on social grounds, as in the case of all village hydro schemes, but also on financial grounds. It can be seen that IRRs of projects are below the interest rates paid for the loans (16%). If there is no grant component associated with the project, the community will find it difficult to pay off the loan solely with the income they receive from the sale of

[69] Detailed methodology and calculations are available from the country reports.

electricity. Unlike the ESD project-based schemes, the charging rate at Site 1 is not satisfactory for it to remain financially viable.

Clearly the investment in Seetha Eliya can easily be justified by private sector financing owing to its high IRR, while Seetha Eliya itself avoids the high cost of grid-supplied electricity.

In the sensitivity analysis we considered several cases, in particular the impact on the variations of the capital costs and the financing conditions on the IRR and the IRRci. Among the series of cases analysed, the most important was the sensitivity of IRR and IRRci to the capital costs and tariffs. This implies that the profitability and sustainability of the schemes will depend a great deal on the ability to build low cost schemes with high plant factors, and deliver services based on realistic tariffs, i.e. a dynamic policy of tariffs, while taking into consideration the ability of the beneficiaries to pay.

1.4 Conclusions from Sri Lanka

- Village hydro[70] projects are primarily meant for off-grid rural electrification in remote locations and they tend to show poor financial viability on their own.
- With a grant component similar to that of the ESD project, these schemes could be financially viable, but the electricity tariffs need to be kept at a reasonable level as in the case of Kandaloya site.
- Within the community-owned village hydro (VH), small-scale individual end-use activities such as battery charging and ice-making are more sustainable than large community-owned end-use activities such as rice milling.
- Private, productive end-use activities such as electricity use in a tea factory make MH schemes very attractive in terms of their financial viability.
- Extension of the national grid into areas where village hydro schemes have already been established jeopardises cost recuperation, contributing to poor sustainability of these projects due to their customer base being affected.
- It is worthwhile exploring the possibility of grid connection of such micro hydro projects as an end-use where excess energy can be sold.

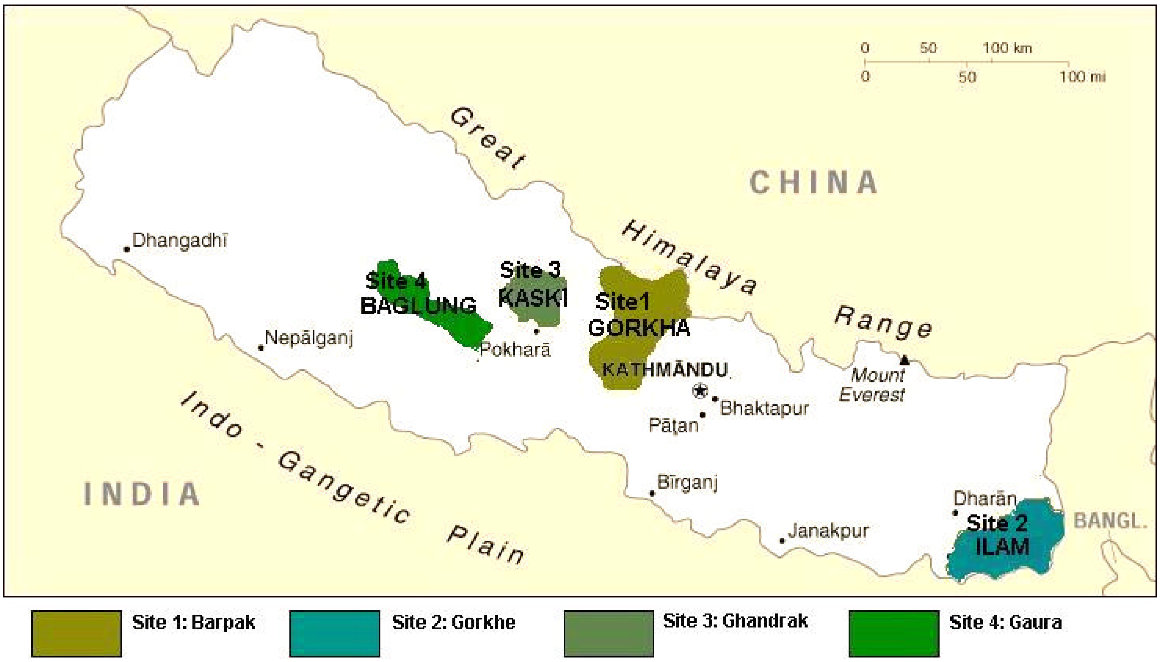
[70] The concept of village hydro was introduced by ITSL and refers not only to the implementation of the scheme, but also to the involvement of the local population from the decision-making process until the management.

2. NEPAL

2.1 The Sample and Assumptions

The study areas include three MHPs located in the hilly regions of Nepal in the Western Development Region in the districts of Gorkhe, Kaski and Baglung where about 134 MHP plants of more than 10 kW capacity (about 37%) are located. One MHP has been considered from Illam District of Eastern Development Region where there were 35 MHP (about 10%) above 10 kW capacity. Attention was given to the selection of plants with electrification as well as processing facilities where power has been generated using cross flow and Pelton turbines.

Figure A-2: Map showing the locations of the case study sites in Nepal



The general characteristics of the selected plants are as presented in the table below.

Table A-7: Selected Sites and Criteria, Nepal

Region	Scheme	Owner	Capacity (kW)	Turbine	End-uses		
Western	Barpak	Community	50	Pelton	Milling	Lighting	Other
Western	Gorkhe	Private	25	Pelton	Milling	Lighting	Other
Western	Ghandruk	Private	50	Pelton	Milling	Lighting	Other
Eastern	Gaura	Private	25	Cross flow	Milling	Lighting	Other

2.2 Case Study Details

2.2.1 Site 1: Barpak Micro Hydro Power Project

Village and Project Overview

This plant is located in Chhara Village, ward No.5 of Barpak Village District Committee (VDC) in the Gorkhe District situated in Western Development Region.. The site is situated in the northern part of Gorkhe District and is not accessible by the road. The plant is located 3.2 km from the settlement area. The source, Ghatte Khola, is located 375 m from the powerhouse. The annual income of the users is estimated at US$36-72.

Works started in September 1990 and were completed in June 1992. There were no major problems apart than difficulties in the transportation of construction materials and plant to the site. The plant has been able to provide services to 538 households, covering 3,362 people.

The consumers and other local residents were involved in civil construction works. The consumers contributed labour while other local residents were paid on a daily basis according to their skill. The borrower had to bear the cost toward the civil construction.

Table A-8: Barpak Scheme Profile (US$1998)

Capacity of MHP:	Design capacity: 50 kW Effective capacity: 30 kW[71]
Start date:	1992
Total Capital cost ($1990): of which Electromechanical: Civil works: Other (inc. trans/dist)	US$64,757 US$57,356 (88.6 %) US$4,344 (6.7 %) US$3,057 (4.7 %)
Loan interest:	17%
Loan amount:	US$35,913
Subsidy:	US$15,812
Household end-uses:	On average 3 bulbs of 25 Watts per household. Morning 05.00h-06.00h, evening 17.30h-22.00h.
Productive end-uses:	Ropeway, sawmill, grain milling.
Tariff for domestic use in 1999: Productive end-uses (sawmill, etc.):	38 US cents per month for 25 W bulb (fixed tariff) 6 US to 7 US cents per kWh (metered)
Cost per installed kW:	US$1,295

The use of power for commercial application seemed encouraging. A ropeway[72] of 2.3 km in length was established to operate cable cars, linking Barpak with Rangrung village. It was designed by Himal Hydro General Construction Co, Nepal, with a total load capacity of 300 kg. Two cable cars are attached with 150 kg payload each. A total of 30 kW is required to operate the system. The carrying time from Rangrung to Barpak is 15 minutes. The total system was completed at the cost of US$100,000,

[71] Effective capacity in 1998, source ITDG.
[72] This scheme was badly damaged. The topography and the design seem to be the main causes.

funded jointly by British Embassy, ITDG and Northern Gorkha Development Group (NGDG). Local people contributed about 9 percent of the total cost in kind.

Table A-9: Source of Financing Ropeway between Barpak and Rangrung

SN	Source of Funding	Amount in US $	%
1	British Embassy	65,714.29	65.71
2	ITDG	14,285.71	14.29
3	NGDG	11,428.57	11.43
4	People Contribution	8571.43	8.57
Total		100,000.00	100.00

The ropeway is completely managed by the community. It has a nine-member management committee fully responsible for operating and managing the system. The management charges US$0.07 per kg for goods transported.

The owner established an agro-processing mill, at a cost of about US$971, which was supplied by Katamandu Metal Industries (KMI). The mill has one rice huller and one grinder, consuming 4 kW of power for each unit. The respective processing costs are 1 US cent per kg and 0.9 US cents per kg. The huller has capacity to process 50-75 kg per hour while the grinder can process 34-41 kg per hour. A total of 20,000-25,000 kg of paddy is hulled annually at present. The grinder is able to process 60,000-80,000 kg of wheat, maize and millet annually.

Other Micro Hydro Plants

A traditional water wheel is still working at Baluwa village, located at Bhalswara, about 4 km from Barpak village. It is mainly operated for agro-processing and the rates are some 14 percent higher than those fixed by the owner of Barpak. However, the rate for grinding is about 13 percent lower than the rate fixed by Barpak’s owner. In addition there is one peltric set of 1 kW capacity installed around 6 km outside of the Barpak village. The power is used for lighting the owner’s own house only. The national grid is located roughly 1.5 days walking distance away.

Financial Results

The results show that without subsidy the IRR after financing, expressed in current values, is 22.8%, which is a good return. However, the results expressed in constant dollars show a lower return of 17%. This latter rate is still in-line with the interest rate charged by ADBN. The main explanation is that the increment of prices in current terms is not correlated with inflation.

2.2.2 Site 2: Gorkhe Micro Hydro Project

Village Overview

This plant is located at Rupatar village of Illam District in Eastern Development Region. The plant is situated at a walking distance[73] of about 2 hours from the nearest roadhead whereas the source, Jogmai Khola, is located at about 500 m from the powerhouse.

The annual income of the middle-class consumers is estimated at US$429-714. The average income of the lower class family is estimated at US$171-286. The plant is

[73] All distances expressed in hours are walking distance.

currently providing electricity services to 12 households with a population of about 80. The owner intends to expand the services to include an additional 55 households with a population of 450.

Project Overview

The Gorkhe water turbine mill was completed in 1984. The plant has a 25 kW capacity and was the first plant installed in the Illam District. The cross flow turbine was designed, manufactured, supplied, and installed by Development Consultancy Services (DCS), who carried out the technical survey. ADBN sub-branch office at Nayabazar conducted the financial feasibility analysis. The owner supervised and supported the costs of all the civil works.

The electrification component was added in 1986, with battery charging and a drier installed in 1988. Domestically, electricity is used for lighting, radio, televisions and ironing. The bulbs are easily available for US$0.43-1.00 in local markets. The consumers are also using low wattage electric cookers known in Nepal as 'Bijuli Dekchi'.

Table A-10: Gorkhe Scheme Profile (US$1998)

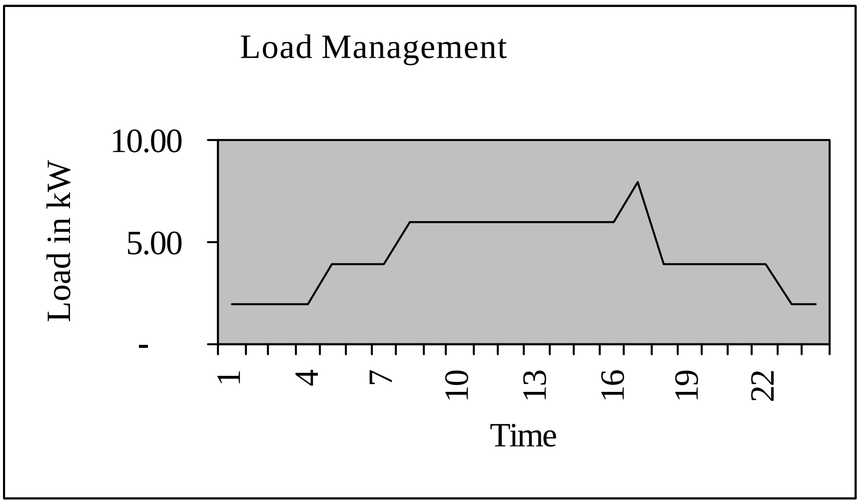
Capacity of MHP:	25 kW
Start date:	Milling – 1984 Electrification, Battery Charging and Cardamom Drying – 1986
Total Capital cost: of which Electromechanical: Civil: Other	US$16,374 US$10,311 (63 %) US$3,479 (21.2 %) US$2,584 (15.8 %)
Loan:	US$8,269
Subsidy:	US$5,469
Repayment period:	10 years
HH consumption:	2-5 bulbs, 1 h/morning and 4.5 h/evening.
Productive end-uses:	Battery charger, cardamom drier.
Tariff domestic end-use:	31 cents per month for 40 Watts (fixed tariff)
Cost per installed kW:	$655

Other facilities for income generating activities were installed in the next phases. The owner installed a processing mill and agro-processing units at the cost of US$1,332 and US$1,645 respectively. The facilities comprise of a huller, grinder and oil expeller. He borrowed US$893 from ADBN as a working capital in 1986. The processing charges in 1999 were: hulling, 0.6 US cents per kg; grinding, 1.25 cents/kg; and expelling, 1.56 cents/kg. These rates are higher, in nominal terms, than those fixed some years ago.

The owner expanded his activity further in 1988, installing a cardamom drier supplied by DCS as a pilot project. The drier was supplied at a cost of US$1,343, of which DCS paid 50 percent as part of their promotion. The owner has contributed the balance - US$672, as his equity. The cardamom processing unit works seasonally for about four months between August and November. The owner dries the cardamom harvested on his farm, producing around 125 kg of dried cardamom annually from 400 kg of green cardamom. The final dried cardamom is of a fine quality and fetches a good price in the market compared with cardamom dried in the traditional way.

The owner used his own resources to establish the battery charger. There is a constant load of 2 kW from the battery charger throughout the day. The load increases during daytime mainly due to the operation of a processing mill. The load characteristics of the plant are presented below. The rate for battery charging varies as per its capacity and is set at 63, 31 and 19 US cents for 12, 8 and 6 volt batteries respectively.

Figure A-3: Load Characteristics of Gorkhe Micro Hydro Plant



The owner fixes tariffs for domestic end-uses and income generating activities. The consumers have no complaint about the present tariff levels. An increment was made on initial processing charges fixed during the year 1985-1990 for hulling, grinding and expelling by 100, 300 and 50 percent respectively. This rate remained unchanged for the years 1991-1995. The processing charges were again revised in 1996 and fixed at 33 and 100 percent above the 1991 rates for hulling and grinding, whilst the rate for oil expelling was reduced to 33 percent of the 1991 fixed rate.

Financial Analysis

Gorkhe has the lowest cost per installed kW. This is certainly due to the fact that it is principally aimed at providing mechanical power and as such the capital cost per installed kW is relatively low. The return on the capital invested is 32% in constant dollars. If the scheme was not subsidised, the internal rate of return is above 17% in current dollars, but just 4% in constant dollars because of the disconnection between the rate of inflation and tariffs.

Other Existing Micro Hydro Plants

A traditional water wheel is located about 4 km walking distance from the plant and is mainly used for agro-processing. The charge for processing is 1.4 US cents per kg, 0.7 cents/kg and 2.15 cents/kg for hulling, grinding and oil expelling respectively[74]. The charge for hulling is 150 percent higher than that fixed by Barpak's owner, the rate for oil expelling is maintained at the same level and the rate for grinding has been maintained at around 38 percent less. There is also a MHP plant of 64 kW, Gorkhe Sana Jal Vidyut, located at about 1 hour walking distance. The plant was established by the Small Hydro Power Development Project, funded by the Nepalese Government.

[74] Usually charges are per 40 kg.

The plant is currently under utilised due to limited end-uses and NEA district office approached the owner to take over the plant. It requires highly skilled operators to operate the plant and there is no plan at present to expand its services. The national grid is located at about 1 hour walking distance and there is no programme to expand their line to that area.

2.2.3 Site 3: Ghandruk Micro Hydro Project

Village Overview

The plant is located in Ghandruk village, in Kaski District, Western Development Region. It is about 6 hours walking distance from the nearest roadhead. The distance from the nearest trail road to the site is about 100 m. The plant is located at about 200 m from the settlement area, whereas the source, Chane stream, is located at 2.3 km from the powerhouse.

The average annual income of consumers involved in business is estimated as US$2,000-US$7,000. The average annual income of the middle class and lower class family is estimated as US$430-US$700 and US$170-US$210 respectively. Agricultural production and tourism are the main occupations of the community. The village is en-route to Annapurna base camp and is considered as one of most beautiful Nepalese villages.

Project Overview

The agro-processing mill was completed in 1985 and the electrification component was added in 1988. During the implementation phase there were no major problems apart from the transportation of construction materials and plant machinery to the site. A pelton turbine and generator were imported from Stamford, UK. The system was designed, installed and supervised by DCS.

The plant experienced serious technical problems after it came on stream: low output was observed and the turbine shaft was broken after installation. The penstock pipe was damaged during the test run of the plant as a result of its poor quality and poor workmanship. DCS reinstalled the penstock pipe free of charge. Because of this incident the supplier installed a separate 16 kVA diesel generator in July 1991 which supplied power nightly until the MHP plant started operating again.

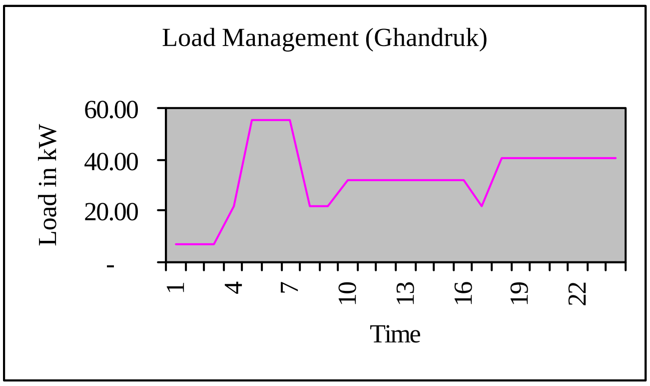
Table A-11: Ghandruk Scheme Profile (US$1998)

Capacity of MHP:	50 kW
Total Capital cost of which Electromechanical: Civil: Other	US$112,597 US$89,910 (79.9 %) US$19,308 (17.1 %) US$3,379 (3 %)
Start date:	Mill – 1985, Electrification – 1988.
Loan interest:	17%
Loan:	US$14,481
Subsidy:	US$73,499
Hours of usage per day:	Processing mill 6 hours per day.
Tariff for domestic end-use: Hotel and lodges: Productive (sawmill):	0.8 cents /W/month 1.2 cents /W/month 1.2 cents /W/month
Cost per installed kW:	US$2,252

The power plant supplies electricity to 241 households covering a total population of 1900 people. The plant also supplies power to 22 hotels/lodges and 6 restaurants. Heating appliances are used by all the hotels and lodges. The plant is managed and operated by the community with the support from Annapurna Conservation Area Project (ACAP), a Non-Governmental Organisation (NGO). The community provided both cash and voluntary work estimated at US$8,132. Daily wages were paid to the non-beneficiaries. The borrower and ACAP contributed the remaining amount required for the establishment of plant.

Most of the energy consumption takes place during the morning as a result of the water heaters and refrigerators used at hotels and lodges. The load improved after the operation of processing and saw mill units. Now the load is relatively uniform during whole day and evening. Load management becomes difficult during the dry season and with the increase of domestic consumption. The load characteristic of Ghandruk MHP plant is shown below.

Figure A-4: Load Characteristics of Ghandruk Micro Hydro Plant



There are no connection or fixed charges, but a reconnection charge of US$1.43 applies if the consumer's consumption exceeds the power allocated[75]. For the processing unit, power supply is available from 10am to 4pm.

Financial Analysis

Ghandruk is the least profitable scheme in financial terms. Even with the subsidy, the return for the investor is just over 10% in current values and 1% in constant dollars. The relatively high initial capital cost[76] and the tariffs policy are key factors, explaining this low profitability.

Other Micro Hydro Plants

A traditional water wheel, mainly used for agro-processing, is located two hours walking distance from the plant. The processing charges are US cents 0.4 per kg for hulling and US cents 1.1 per kg for grinding.

A micro hydro plant has recently been installed at ward no 9 of Ghandruk with a total installed capacity of 6 kW. It is located at a walking distance of about 3 hours from the existing MHP plant. The plant is managed and operated by the community and the

[75] Households are fitted with low cost circuit breakers. Power is automatically cut off when consumers use more than the wattage allocated. Allocated supply usually falls between 40 W - 100 W.

[76]. The capital cost per kW of Ghandruk is the highest of the four schemes of the Nepalese sample.

users' committee fixes the tariff. The tariff is US$0.57 per month for 40 Watt. This is at least 100 percent higher than the tariff of the existing MHP plant in Ghandruk. A newly constructed hotel has installed a diesel generator due to the lack of available power from the existing MH plant.

The charge for hulling is 150 percent higher than the rate at Ghandruk MHP. The rate for oil expelling is maintained at the same level whereas the rate for grinding is about 38 percent lower than the rate fixed by the owner of Ghandruk MHP. The national grid is located about 1 hours walking distance away.

2.2.4 Site 4: Gaura Rice Mill (Harichaur Micro Hydro Project)

Village Overview

The plant is located in Harichaur village in Baglung District in Western Development Region. It is 8 hours walking distance from the nearest roadhead and 30 minutes walking distance from the nearest trail road. The plant is located at the bank of Daram Khola, which is about 700 m from the village. Harichaur was previously the district headquarter, later shifted to Baglung. It is situated en-route to Dhorpatan, one of the promising areas for tourists and trekkers. There is a holy place called Utar Ganga, which is located at a walking distance of about 3-days from the settlement. There is a police station, a hospital, boarding school and short-wave communication transmitting station. The main occupation of the community is agricultural production.

The annual average income of the consumers is estimated as US$170-US$290. The plant supplies electricity to 236 households including 11 offices and institutions covering 1575 people. Most of the power is used for household lighting, television and radios and to run the agro-processing plant.

The daily time saving of 1-2 hours has been used by the community to set up a kitchen garden and operate a Non Formal Education (NFE) programme. It is estimated that about 70 percent of the community (an increase of about 45 percent) have become literate and the enrolment of girl students has increased every year. The study hours of the students has also increased, by 1-1.5 hours daily.

Project Overview

The initial system was designed, installed and supervised by DCS who manufactured and supplied the cross flow turbine. Nepal Machine and Steel Structure (NMSS) also designed and installed a new turbine in 1997 which enhanced the output by an additional 2 kW.

Table A-12: Gaura Scheme Profile (US$1998)

Capacity of MHP:	25 kW
Start date:	1987
Total capital cost: of which Electromechanical: Civil: Other costs (incl. transp/dist.)	US$54,000 US$35,785 (66.3%) US$15,330 (28.4 %) US$2,885 (5.3 %)
Loan interest:	17% average interest rate
Loan:	US$26,394

Subsidy:	US$8,053
Repayment period:	12 years including 3 years grace period.
Household and institutional end-uses:	On average 3 bulbs of 25 Watt for lighting 05.30 h-06.30 h in the morning and from 17.30 h- 22 h in evening.
Productive end-uses:	Agro-processing (huller, grinder expeller).
Tariffs domestic lighting:	US cents 34 /25W/month
Cost per installed kW:	US$2,160

The processing mill was established at a cost of US$2,080. The owner carried out all the civil construction. Local skilled and unskilled labour was used in the construction works.

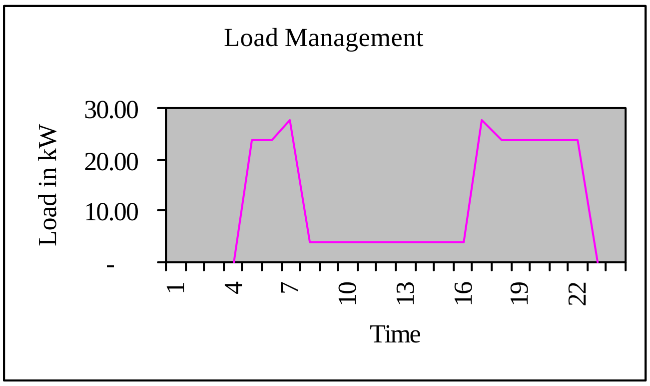
The loan repayment schedule for the plant was arranged for 12 years, which also included a grace period of 3 years. The borrower had to repay the loan for working capital within 12 months and there was no provision for a grace period for such a loan.

The consumers and other non-beneficiaries were involved in civil construction works. The consumers provided voluntary labour whereas non-beneficiaries were paid as per the prevailing rate depending upon their skill.

The morning and night-time loads are mainly from household lighting. A battery-charging service has been provided which was developed by DCS in 1997. The battery lighting system has been installed in the hospital to provide light for the maternity ward in case of an emergency.

The load characteristics of the plant are shown in the chart below.

Figure A-5: Load Characteristics of Gaura Micro Hydro Plant



The processing charge for rice hulling was fixed at 0.57 US cents per kg of paddy from 1984 - 1986. The rate was increased from 1987 to 1.7 cents/kg. The grinding charge was 0.68 cents/kg, which was increased to 2.9 cents/kg in 1987. The oilseed was expelled at 3.8 cents/kg and was increased to 8.4 cents/kg in 1987[77]. However none of these rates were changed after 1987 which signifies a sharp decrease in constant values.

[77] Usually charges are per 10kg.

Financial Analysis

The internal rate of return on the capital invested is over 13% in current values but just 3% in constant values. If we assume that the plant was not subsidised, the internal rate of return would be 7.39% in current values, with no return in constant values. This is predominately the result of the stabilised processing tariffs which were kept unchanged from 1987 onwards.

Other Micro Hydro Plants

Harichour has numerous MHPs in its vicinity. An improved water wheel was established in 1980 and is located at Hatiya village; about 45 minutes walk from the MHP. It has the same rates as the plant investigated. Also, a MHP plant of 7 kW capacity was installed a decade ago under the loan assistance from ADBN and with subsidies from the Nepalese Government. The national grid line is about 1-days walking distance from Harichour. A community-managed micro hydro of 50 kW capacity has recently being installed at a working distance of about 45 minutes. The plant was established with the grant assistance of US$29,851 from the Canadian Co-operation Office (CCO). The balance fund was arranged through a subsidy from the Government of Nepal, a loan from ADBN and equity from the community.

3. PERU

3.1 The Sample

This economic and financial analysis is based on four small-scale hydroelectric plants. The first case concerns Atahualpa farming co-operative. The power generated by this MHP is used for income-generating activities, as well as for domestic and institutional purposes. A small entrepreneur owns the second plant and the power generated is used entirely for an incubating plant. The third case consists of a public electricity service in the district capital of Pedro Ruiz. The MHP is managed by the municipality and provides electricity to the town of Pedro Ruiz. The fourth case is a public service in the Pucará District, managed by an electricity distribution company.

Table A-13: Selected Micro Hydro Schemes in Peru

	Atahualpa	**Yumahual**	**Pedro Ruiz**	**Pucará**
Owned by	Community	Private Owner	Community	Private Owner
Capacity (kW)	35	10	185	2 x 200

Figure A-6: Map showing the locations of the case study sites in Peru

3.2 Case Study Details

3.2.1 Site 1: Atahualpa Farming Co-operative

Village Overview

The project's objective was to provide the co-operative with a permanent and reliable source of energy to improve the development of a previously implemented and flourishing agro-industrial activity. Before putting the MHP plant into operation, the co-operative had facilities for transforming farm products and had other machinery. These were fed by a low powered diesel generator with limited output and high production costs. The farming co-operative of Atahualpa-Jerusalén Workers has about 58 members at present, of which 48 are active members and the other 10 are retired.

Project Overview

The 35 kW MHP was set up as part of a demonstration project that ITDG promoted in Cajamarca. The power generated by the MHP is used for productive activities, and for domestic and institutional purposes.

Table A-14: Atahualpa Scheme Profile (US$1998)

Department, Province and District:	Cajamarca
Settlement:	Porcón
Owner:	Atahualpa-Jerusalén Farm Workers' Co-operative
Plant capacity:	35 kW
Start date:	March 1992
Total project cost: of which Electromechanical: Civil work: Other costs	US$82,541 US$31,116 (37.7%) US$19,009 (23 %) US$32,416 (39.3 %)
Number of domestic users:	28 families, no charges, assumed part of the benefits of the Co-operative.
Use of energy:	Carpentry workshops and milk processing plants. Domestic and institutional purposes (lighting, cooking, TV and radio); battery charging, and other services.
Cost per installed kW in	US$2,358

The only workshops that produce earnings using the electricity generated in the MHP are the carpentry workshop and the milking and dairy unit. Both are seasonal activities and the annual consumption was estimated taking into consideration this important parameter. In fact, the bulk of the consumption is currently absorbed by domestic end-uses.

The co-operative has a registry of users in which they record the number of fluorescent tubes and light bulbs. On average 3 fluorescent tubes and one light bulb per home are used, as well as electric appliances for both domestic and institutional purposes. The annual consumption[78] was estimated at 56,337 kWh/year according to the following breakdown.

[78] Unfortunately the electricity meter installed in the MHP was not working properly and these figures had to be estimated.

Table A-15: Energy Consumption for Productive and Domestic End-Uses (kWh), Atahualpa

Domestic and institutional end-uses	47 347
Carpentry workshop	6 909
Milk and dairy	2 081
Total	**56 337**

Financial Analysis

The MHP was financed with contributions from the Peru-Canada Countervalue Fund (67%), ITDG (12%) and the Atahualpa Co-operative, which provided US$12,000 for machinery as well as manpower and local materials for civil works. ITDG assumed the commitment to supervise the works from start to finish and to train the operating and maintenance staff. The finance structure was as follows (overleaf):

Table A-16: Financing breakdown for Atahualpa Micro Hydro Plant (US$)

			Own	**FGCPC**[79]	**ITDG**
		Total	Contribution		Contribution
1.	Institutional expenses	1,736,600	0	1,260,400	476,200
2.	Investments	4,188,400	1,488,400	2,700,000	0
3.	Installations	500,000	0	500,000	0
4.	Transport	472,000	0	171,000	301,000
TOTAL		6,897,000	1,488400	4,631,400	777,200

Source: Power and Productive Development of the Cajamarca River Basin, MHP of Huacatas and Atahualpa, June 1990. Average exchange rate = 0.21 Soles per dollar (according to Cuanto S.A. Institute).

The selling price of the electricity was derived from the opportunity cost of the electricity produced by a diesel generator, estimated at 18 US cents per kWh in 1998. The calculations were based on the average price of the fuel in the area, obtained from local distributors and gave a life expectancy of 7 years for the diesel generator. We have assumed that the selling price increases according to the inflation rate.

Under these assumptions, the internal rate of return is 17.5% in current dollars and 14.5% in constant dollars. Our calculations show that the project could be financially viable. However, this remains linked to the management of the scheme and policy regarding the payment of the electricity. Domestic users, who are not charged for this service, absorb the bulk of the power produced. It is obvious that a system of tariffs in line with the purchasing power of poor end-users will lead to a much lower IRR.

The initial investment in Atahualpa's MHP had a high grant component as ITDG was promoting it as a demonstration project. Standards of living have improved as a result of the domestic supply of electricity for lighting, entertainment and even for cooking (1 kW to 2 kW electric cookers). Despite this, little value is placed on the energy

[79] FGCPC: Fondo General Contravalor Peru Canada.

produced by the MHP, due to the lack of control, limited internal regulations and above all, the non-existence of a charge for its use.

By making more electricity available, the project has also had a considerable impact on institution building. This is evident in the mechanisation of inventory and cost controls, lighting of public areas such as roads, and stronger income-generating industries. Religious activities have also been boosted by a radio station and lighting for the church. It is worth pointing out that religion plays a prominent role in community life and religious activities have been made more comfortable since spot lights, loudspeakers, videos and electric organs were installed.

3.2.2 Site 2: Micro Hydro for Productive End-Use: Yumahual Scheme

Business Overview

All the production of Yumahual scheme is devoted to supply power to a privately-owned broiler chicken farm. The micro hydro scheme and the chicken farm belong to the same person. The initiative to incubate fertilised eggs was promoted as an across-the-board business strategy aimed at reducing costs by incorporating activities and/or processes, thus severing the dependence on suppliers of broiler chicks. Only one person in the MHP is involved in supplying energy to the incubating plant. The same person is also responsible for maintenance, for the entire process of incubation and hatching of baby chicks, as well as for selling soft drinks.

Project Overview

The MHP has the capacity for 11 kW, of which 8.77 kW are used for incubation and the remaining 2.33 kW would be for future operations. The initial investment in the MHP in Yunahual was US$37,082, which was financed partly with a loan from a financial entity (82.2%) and partly with a donation from ITDG (10.3%). The investor contributed the remaining 7.6%.

Table A-17: Yumahual Scheme Profile (US$1998)

Department and Province:	Cajamarca
District and Settlement:	Magdalena, Yumahual
Start date:	October 1998
Plant capacity:	11 kW (for 4 months a year the capacity of the MHP is 4 kW due to the shortage of water)
Owner:	Mr. Andrés Leoncio Sangay Terrones
Total project cost: of which Electromechanical: Civil works: Other (inc. trans/dist)	US$37,082 US$14,062 (37.9 %) US$13,640 (36.8 %) US$9,380 (25.3 %)
Loan:	US$30,000 in 1997
Interest and repayment period:	On average 6.5% per year; 5 years.
Use of energy:	Operation of an incubating plant.
Cost per kW installed:	3,371 US$

In practice the effective capacity is 4 kW during low water stages in the Yumahual watercourse (four months a year). The following will be the maximum annual production capacity of the MHP:

3 months $\times$ 30 days $\times$ 24 hours $\times$ 4 kW = 11,520 kWh
8 months $\times$ 30 days $\times$ 24 hours $\times$ 11 kW = 63,360 kWh

This means that the MHP will have a maximum annual production capacity of 74,880 kWh a year. This limited capacity requires an adequate management of the annual load.

It is worth noting that there were maintenance problems as rocks shifted due to rainfall, causing the MHP to stop operating on four occasions when it was necessary to resort to a small generator that was used for more than 26 hours in 1999, consuming 12½ gallons of petrol.

The MHP supplies electricity for the incubation and hatching compartments, lighting inside and outside the incubating plant as well as for charging a battery that supplies power to a short wave radio receiver/transmitter used for communication with the farm.

Table A-18: Energy Distribution in the Incubating Plant, Yumahual

Load	**Power (kW)**	**Daily working hours**	**Energy (kWh)**
Incubator (1 of 3 units)	4,5	24	108,0
Hatcher	4,0	24	96,0
Battery charger	0,3	12	3,6
Lighting	0,4	6	2,4
Total			**210**

Source: Interview with the power plant operator.

A correcting factor of 0.8 was considered, because the incubator does not consume 4.5 kW continuously as it has a power capacity of 1.5 kW that works perfectly. The total annual consumption is therefore:

210 kWh/day $\times$ 30 days $\times$ 12 months $\times$ 0.8 = 60,480 kWh/year.

Our analysis is based on this figure.

Comments

The same methodology and assumption as Athahualpa were used for Yumahual. The selling price of the electricity was derived from the opportunity cost of the diesel generator, which was estimated at 17 US cents per kWh in 1998· The calculations were based on the average price of the fuel in the area, obtained from local distributors and a life expectancy of 7 years for the diesel generators. We have assumed that the selling price increases according to the inflation rate.

Under these assumptions, the internal rate of return in current dollars is 17.6% and 14.6% in constant dollars. This shows that the project could be financially viable. For the entrepreneur the choice of micro hydro for electricity generation seems a better option since the cost per kWh is cheaper than the cost of a diesel generator. However, if we assume that there are no incentives, such as soft loans, the up-front capital could be a major constraint in the replication of similar micro hydro projects.

The promotion of small-scale companies in Cajamarca requires a change in behaviour patterns, as, by tradition, this area primarily produces consumer goods (mainly farm products). In this respect, the Yumahual MHP has two potential roles, the first to generate income, and the second, in demonstrating alternative end-uses for MH power.

3.2.3 Site 3: Public Electricity Service in Pedro Ruiz

Village Overview

Pedro Ruiz town is strategically situated at the junction of two main highways. The first of these connects the higher jungle with the northern coast (Chiclayo, Piura, etc.), and the second links the coast and the highlands (Chachapoyas, Celendin, etc.). Consequently, Pedro Ruiz is a resting point for travellers to these areas.

Project Overview

Electricity generating comes from two watercourses - Ingenio and Asnac. The plant design capacity is 200 kW and the effective capacity is 140 kW leading to some shortage of electricity supply in the growing town of Pedro Ruiz. In 1980, MHP activities began under the responsibility of Electronorte (a state-owned regional distribution company). Ten years later, the district municipality of Jazán took over the running of the MHP.

The staff here have not been adequately trained to carry out their jobs. One operator has been there since the previous administration and he took it upon himself to teach the other operator despite the fact he was not well trained. No consideration was given to using skilled staff for corrective plant maintenance, instead people with no MHP training were hired, for example, electricians used to solve the mechanical problems. The plant is consequently rapidly deteriorating.

Table A-19: Pedro Ruiz Scheme Profile (US$1998)

Department, Province and District:	Amazonas, Bongara, Jazán
Town:	Pedro Ruiz
Owner:	District Municipality of Jazán
Start date:	1985
Plant capacity:	Design capacity 200 kW; Effective capacity 140 kW
Total project cost: of which Civil works: Electromechanical: Other costs (inc.trans/dist)	US$1,126,075 US$28,477 (2.5 %) US$806,162 (71.6 %) US$291,436 (25.9%)
Number of users and load management:	722 users. • Monday to Fridays: 10:00 a.m. to 5:00 a.m. (total: 95 hours) • Saturdays: 2:00 p.m. to 5:00 a.m. (15 hours) • Sundays: from 8:00 a.m. to 5:00 a.m. (total: 21 hours)
Cost per installed kW	US$5,630

In order to save energy, the use of fluorescent lights was established, both for domestic purposes and for public lighting. The peak hour is 6:00 p.m., which causes difficulties for certain commercial activities, such as photocopiers.

Financial Analysis

The calculations are based on a historical interpolation from 1996 data - assuming energy demand from 1980 to 1996 grew at 3.10% and connections grew at the rate of population growth (i.e. the 1996 figure for sales is extrapolated backwards). The economic-financial analysis of Pedro Ruiz shows that there is no return in constant dollars when the plant was financed by relatively soft loans. This is mainly due to the high initial capital costs[80] and relatively low tariffs.

The following entities participated in the construction and implementation of the MHP:

Project Funding:	Central Government
Civil Works:	The firm Opil
Electrical-mechanical Equipment and Networks:	Electronorte
Manpower:	Population of Pedro Ruiz and neighbouring communities.

The total investment was slightly over US$0.5 million in 1979.

Table A-20: Structure of the Investment, Pedro Ruiz (US$Current)

	Total US$
1. Land in which the power house is situated	55,728
2. Civil works	1,268,401
3. Electro-mechanical equipment	35,906,336
4. Grids and electrical facilities	12,924,882
Total (US$)	**50,153,346**

Source: Initial Inventory of the Electricity Area at 17th October 1990 adjusted to December 1979.

There are three main categories of income: connections for new subscribers; sales of energy; and other income, such as reconnections or payments for arrears. New subscribers were taken into account for the calculation of the MHP's income from the sale of electricity and other income. Meters were considered part of the capital contribution as the municipality considers them as fixed assets. On average, 92% of the income is obtained from selling the service and from subscriptions.

The rate structure has hardly changed since 1996. Payment dates vary between the first ten days of each month, after which default interest is charged. The rates were

[80] Out of the16 schemes investigated, Pedro Ruiz has the highest cost per installed kW.

established during the previous municipal government by agreement with the council. The population's interest in keeping the service as cheap as possible prevailed.

The registration fee for new users is US$49.00 (since 1997) and they have to buy their own meter and accessories. The average rate per kWh charged is US$0.032. In case of no payment the following sanctions are contemplated:

- Simple re-connection: US$1.12
- Re-connection due to overdue payment: US$1.87
- Unauthorised handling of meter: US$3.74
- Extending the service to another home: US$5.61
- Repetition of (a) and (b): service suspended for 8, 15 and 30 days, respectively.

The default interest rate is equivalent to 4% of the monthly bill per day; the electricity is cut off after 60 days. According to the administrator, no sanctions are being applied at present due to a change in the municipal administration, indicating that consumers have become used to paying their bills on time.

As regards the theft of posts and cables, the administration addresses the culprits directly and demands the respective payment; if payment is refused then a complaint is filed at the police station. There is no fine for offences of this nature.

Table A-21: Income From the Sale of Electricity, Pedro Ruiz (US$Current)

	1996	1997	1998
Income from the sale of energy (US$)	2,134,152	2307629	2,518,682
Average annual consumption	661,680	682197	703,351
Average Price of Energy (US$)	32	34	36
Other income (US$) of which	725,690	632,120	659,607
Reconnections	60,220	15,341	13,932
Payment arrears	174,510	215,511	182,792
Various changes	319,115	408,268	462,883
Others	171,845	-	-
Total income			

Source: District Municipality of Jazán, Electricity Area

Cost Analysis

The total costs are summarised in the following table. Under our assumptions the cost per kWh comes to US$0.14.

Comments:

The initiative of the authorities of Pedro Ruiz and the population in general to take over the MHP marked a significant change in the quality of the services. It must be stressed, however, that municipal elections and consequent changes of authorities do not influence the electricity service. The funds are managed adequately despite the technical and economic limitations. In this respect the current administration has been successful. Nevertheless, the management model is far from being worth replicating, considering its earning potential and the size of its user-base.

It is also worth mentioning that the entire economy was going through a serious crisis in 1990 that affected the management and supply of electricity services. The new legal and institutional framework governing the electricity sector promotes private investment as well as quality. As a result of this state initiative, several municipalities will be handing over the electricity services to concession companies, given the legal, financial and economic guarantees that make it attractive to meet the electricity requirements of users in remote areas.

3.2.4 Site 4: Public Electricity Service in Pucará District

Town Overview

The town of Pucará is a nexus for cities like Chiclayo, Trujillo and Lima, as all farm traders and transport are required to drive through it. Like the town of Pedro Ruiz, farming is the main activity, and the main crops are coffee, cocoa, rice and fruit. The main access to Pucará is the "Marginal de la Selva" highway, a fully paved road (Chilcayo-Pucará) that connects the town with the main towns on the coast and in the jungle (Jaén, Bagua, and Chachapoyas). Pucará is home to major institutions: the district municipality, the medical post, the national police force, and Electronorte, among others.

Project's Overview

The MHP supplies electricity to 972 users in the towns of Pucará and Pomahuaca, consuming an average of 98.4 kWh/month per family, with an estimated power capacity of 53.3%, given the peak hour demand of 120 kW. Business activities have increased since this plant started operating, as farm products can now be traded without restriction. Furthermore, service activities have developed, such as small restaurants, shops, photocopying services, welding, carpentry and sewing workshops, etc.

Table A-22: Pucará Scheme Profile (US$1998)

Department, Province and District:	Cajamarca, Jaén, Pucará
Town:	Pucará
Owner:	1986 – 1991, Electroperú 1991 – 1998, Electronorte 1998 onwards, Gloria Group
Start date:	1986
Number of users:	972 current users, of which 810 have a meter.
Plant capacity:	2 x 200 kW, Effective capacity 200 kW.
Total project cost:	US$454,460
Cost per kW installed :	US$1,136

Water for generating electricity is obtained from El Chaupe watercourse. The MHP has a plant capacity of 400 kW with two power generating units of 200 kW each. The maximum demand is 284 kW. The plant's effective capacity is currently equivalent to that of one generator as the speed regulator of the second unit is damaged and there is a shortage of water during the low-water stage. Consequently, there is an auxiliary thermal generator with an effective potential of 150 kW. The demand during 18 hours a day does not exceed 150 kW, which is equivalent to the power generated by one hydroelectric generator, providing that water is available.

The MHP came on stream in 1986 under the responsibility of Electroperú. Subsequently, in 1991, the management was transferred to the regional company Electronorte. This firm was transferred to the private sector in 1998 and the Gloria group became the plant's new owners. The Electronorte Office in Jaén (a unit of Cajamarca), which depends on the main office in Chiclayo, is responsible for the system.

The MHP in Pucará was financed with the participation of the Agency for International Development (AID) and Electroperú. The latter was responsible for implementing the project. As far as the finance structure is concerned, only the Physical Inventory of the works was accessible, showing the network expansion structure but not civil works or electrical-mechanical equipment. Nevertheless, according to the information obtained from Ministry of Energy and Mines publications, the cost of the MHP was equivalent to US$454,460.

Source of Income

The registration fee for new users is US$50.00. The Jaén office establishes this fee and the finance method. By December 1998, 972 authorised users were registered.

Income from new users' subscriptions, sale of energy and other income were taken into account to calculate the MHP's income.

Table A-23: Estimated Income, Pucará (US$Current)

	1996	**1997**	**1998**
Annual Average Energy (kWh) Income from the sale of energy (US$)	1,306,800 79,458	1,337,428 83,721	1,368,774 59,763
Average price of energy (US$)	6	6	4
Other income (US$) of which	725,690	632,120	659,607
Payment arrears and interest	165,600	267,800	235,600
Reconnection	146,600	76,600	55,400
Replacement and maintenance charges	189,500	172,300	156,400

Source: Interview with the power plant's operator.

The total running costs estimated for 1998 were US$59,351. More than half of this amount was spent on paying the operating and maintenance staff (54%), whilst security service costs were equivalent to 46% of the total cost. Hence the decision to reduce the number of staff.

Financial Analysis

The calculations show that the internal rate of return before financing is just 8% when calculations are expressed in nominal values. This is beyond the discount rate of 18% usually used for projects implemented in Peru. In constant terms and after financing, there is no return.

Comments

Taking into consideration the government's plans to expand the networks, it is very likely that the Pucará MHP plant will be connected to the general Electronorte network in the medium term. This would certainly improve the project's profit margin as the diesel generator would be no longer needed, and staff expenses would be cut down as the electricity supply in Pucará and Pomahuaca would be re-organised and sold through the grids.

The electricity service in Pucará has become more profitable as the management has improved. This improvement in management is in part due to the restructuring of the distribution company that took place before it was privatised.

As in the previous case, the donation is critical in the project's earning capacity, suggesting that even for services of the size of those provided in Pucará, a soft loan financing scheme is required. Pucará is probably within the limits of the type of projects that need strong financial backing in order to operate under the current circumstances in this country. Larger projects would have to be self-sufficient, even if the management acquired higher skills in order to reduce energy production costs and losses, improve distribution and increase income and collections.

3.3 Key Conclusions Peru

In all these cases part of the investment was covered by a grant provided by private organisations or the state. It was difficult to obtain examples of plants where costs were fully covered by the owner. Even in the case of the private owners, part of the total investment (studies, technical assistance among others) was provided in the form of a grant.

At first sight, the financial situation of the projects analysed is not very encouraging. Future prospects may be better however: the economy is fairly stable (the possibility of traumatic changes seems remote); the government is promoting clear regulations for the electricity business; and government policies are placing priority on the struggle against poverty, showing a preference for overall projects in which energy is a component. It is therefore expected that experiences like those of Atahualpa or Yumahual (less than 100 kW) will be disseminated and that under the current regulatory framework, appropriate management alternatives will be proposed for projects like Pucará and Pedro Ruiz (more than 100 kW).

The following are the key lessons to be considered for the future:

- The sustainability of micro hydro plants requires not only adequate technical training in operation and maintenance but also business and managerial training from the design stages of the project.
- The lack of credit for micro hydro is a constraint, but its availability does not guarantee project sustainability. Good project design and careful risk analysis of productive activities are a must.
- The best prospects for economic and financial sustainability exist for projects that use the energy produced for a diversified portfolio of productive activities, and not just for domestic lighting.

- Financial and economical sustainability of a plant will be adversely affected where there are high costs associated with plant installation (due for instance to over-design, wrong selection of equipment.
- Although no conflicts over the use of water were observed in these cases, it is necessary to establish a water utilisation system for low water stages, which does not limit the power generating capacity.

4. ZIMBABWE AND MOZAMBIQUE

4.1 Case Study Details

4.1.1 Site 1: Nyafaru Micro Hydro Co-operative: Domestic and Services End-Uses

Village Overview

Nyafaru Co-operative Farm covers 600 hectares of land. It is run by a committee of seven chosen from the membership at the farm. The committee is accountable to a board of trustees. For purposes of management the farm is divided into units including: the clinic; fisheries; schools crop production and retail. Sub-committees run each of these units.

Until the current hydro project was commissioned, people on the farm depended on paraffin and candles for lighting. A wind generator installed at Nyafaru more than fifteen years ago was never commissioned because it was wrongly designed for the site conditions. The use of solar PV at the clinic and a wind electricity generator at the shop were discontinued with the advent of hydro electricity because the micro hydro plant is more reliable. A diesel engine generator that had been operating on the farm was also disconnected because of high operational costs.

Project Overview

The Nyafaru plant was commissioned in 1995. A Nepalese expert in designing and manufacturing cross flow turbines was hired to help with local construction of a cross flow machine. Four local technicians were simultaneously involved in building-up the turbine and in training with a Nepalese expert. ITDG planned the course and provided overall guidance. The training covered all components of the project, including installation, commissioning, operation and maintenance. A small-scale workshop at Cold Comfort Trust (CCFT) in Harare and the University of Zimbabwe's mechanical engineering workshop provided facilities and materials.

Nyafaru, Zimbabwe, inside the power house

The plant generates about 20 kW reliably, which is used by a shop, a clinic, one primary and one secondary school, and farm staff houses. The scheme is run by the Nyafaru Hydro Committee (NHC), composed of representatives from the various units using the electricity, the chairperson of the co-operative, and three co-opted teachers. The hydro committee is responsible for setting-up and implementing electricity tariffs. A fixed monthly charge is levied on each user. The tariff levied per user depends on the upper limit of the load for that consumer. A miniature circuit breaker (MCB) installed at each user sets this upper limit. The tariffs are set at socially attractive levels supported by a generous subsidy from the school. When the hydro plant incurred a debt of about US$532 in 1998 (Z$ 11,400), the school provided an interest free loan.

The domestic load consists of about twenty households, mostly teachers, nursing staff and the co-operative chairman. Other farm workers have not yet been connected mainly because they have not been able to afford the installation charge. Of the connected households about 80% already have radios and televisions powered by the plant. Benefits have been spread to the community beyond the farm through electrification of the clinic, schools and shop. Over 200 school children on the boarding facility have moved away from using paraffin lights and candles, to electricity. A weaving shop used mainly by women has been electrified. This has enabled the women to engage in their weaving activities well into the evenings. The improved service at the clinic benefits mainly women and children who are in the majority within the farm and the surrounding rural community. Women's presence in the committee is a sign of their participation in the running of the plant. The provision of electricity for refrigeration has played a vital role in increasing sales to a larger number of customers, some coming from distant places like Magadzire, Tsatse and Gairezi.

There is a marked difference between the load pattern at planning stage and after commissioning. During the planning phase an analysis of demand showed a peak of 17.5 kW and an average of 6 kW. However, the demand forecast included a mill and a trout farm, which have not been connected.

Table A-24: Nyafaru Scheme Profile (US$1998)

Capacity of MHP:	20 kW
Start Date:	1995
Total Capital Cost: of which Electromechanical: Civil:	US$66,156 US$21,382 (32.3 %) US$14,980 (22.6 %) US$29,794 (45 %)
Connection charge per HH:	US$73
End-Uses:	Domestic, services.
Tariff hh/month:	US$2.65 (Z$30) per 5A connected initially, now US$7.1 (Z$80) per 5A connected (1999).
Cost per installed kW:	US$3,307

Financial and Economic Analysis

The Nyafaru scheme was financed through grants from external organisations and contributions by the Nyafaru community. The grants were negotiated by ITDG in close liaison with the community. The main funders for the design and construction of this scheme included: the European Commission; Cadburys; the UK Overseas Development Agency (ODA); and German Agro Action (GAA). These funds covered technical inputs from ITDG, local contractors, local and external consultants, local labour and all materials including electricity transmission and distribution lines. The grants were also extended to connecting the shop, clinic and a few blocks at the school. Each of the connected user/group paid for their connection. These users consisted of the remaining school blocks, teachers' and nurses' houses.

The investment cost of the scheme was about US$3 307 per kW[81]. However, this was a prototype project with high external costs and the design was rather conservative.
A tariff based on meeting operation, maintenance and depreciation costs has been recommended, but the hydro committee is not yet implementing it. Indications are that unless tied with some income generating activities the communities are unable to meet the tariff. When the project came on stream only the shop, the clinic and the school were connected. By the end of 1996 about nine households had been connected. The fixed monthly charge of US$2.5 (Z$30) for each 5A connected in 1996, had risen to US$7.1 (Z$80) in 1999. In other words, a consumer with a 15A supply paid US$21 per month. This type of tariff structure has encouraged the consumer to fully utilise the installed capacity whilst stimulating the connection of new consumers.

From the records available the plant has experienced down time of about 50 days per year. The annual electricity consumption is estimated at about 57 000 kWh. However, meter readings of power over a nine-month period from November 1997 seem to suggest that the load factor is around 43%.

In trying to build up a picture of the cashflow situation for the plant the following points were noted:

- The cost of getting the power from the nearest distribution pole to the user constitutes the connection costs and this is borne by the user.
- Average connection costs have been used in the analysis.
- It is assumed that the Civil Engineering Index on plant can be used to predict inflation on the power plant.
- It is assumed that investment costs for the plant was incurred over one year only.
- Inflation on labour is assumed to be about 30% per annum. This is confirmed by an analysis of the payments to the operator.
- The US$532 (Z$11,400) borrowed from the school to pay for otherwise avoidable damage to the equipment was in the first quarter of 1998. It is assumed that in future preventive maintenance will be practised to avoid such disasters.
- It is assumed the tariff increases by 15% each year. ZESA is increasing its tariffs at 15% per quarter.

Nyafaru scheme was almost entirely funded by grants. The IRR is extremely high if the grants are considered as an income. We have therefore assumed that the capital is borrowed from a renewable energy fund such as the UNDG-GEF Solar fund. This fund levies an annual interest rate of 15%. We have considered a repayment period of five years. A period of twenty-five years has been selected as the minimum life of the plant. Under these assumptions the internal rate of return is 8% in current terms and there is no return in constant dollars. This is largely due to the rather low load factor and the high initial capital cost, and the tariffs increase which is below the rate of inflation.

[81] S Fernando, S Khennas and K Rai, ITDG Zimbabwe Micro Hydro Project Evaluation, 1997.

4.1.2 Site 2: Svinurai Micro Hydro Mill

Village Overview

This was originally a commercial farm called Tabanchu. It is located at Cashel, about 80 km south of Mutare. In the early 1980s, government bought it for resettlement purposes. This scheme is run by a Micro Hydro Committee, which is composed of elected people from the general membership of the co-operative. The committee is also responsible for setting and implementing electricity tariffs after consulting the general membership. Membership of the co-operative has fluctuated over the years, but averages about 23 people. A committee of seven runs the farm.

Milling is one of the minor activities at the farm. Although it does not stand out as a major activity, the mill has provided the co-operative with a more consistent source of income than the other activities. Apart from the co-operative members, the 280 households in the surrounding community benefit from the milling service. The main beneficiaries are women and children who would otherwise walk up to 8 km to the nearest mill, which is powered by a diesel engine. Apart from unreliability of the diesel-powered mills users would have to pay up to 50% more per bucket milled.

Project Overview

In 1993 rehabilitation work started with the assistance of ITDG. The mill is operated by an worker who checks the whole system about three times a week on average. The operator is a member of the co-operative and is employed full-time. Virtually all repairs are now done at the farm. During peak times the mill operates on three eight hour shifts, seven days a week. A single eight hour shift is the normal mode of operation. Routine maintenance is carried-out by the committee. This involves greasing and replacing bearings, replacing belts and cleaning the intake, channel and forebay.

All members of the co-operative benefit from the milling service and therefore they would like to enjoy a low tariff. However, they also get a monthly allowance as part of their income from the farm activities. Co-operative members are charged 1.5 US cents less per bucket milled than non-members. This forces them to charge reasonable tariffs as they both try to maximise their income and avoid getting overcharged themselves. The operator gets the same monthly allowance and milling tariffs as other members of the co-operative.

Table A-25: Svinurai Scheme Profile (US$1998)

Capacity of MHP:	13 kW
Start Date:	1993
Total Capital Cost: of which Electromechanical: Civil:	US$9,296 US$662 US$8,634
Cost per installed kW:	US$715

Figure A-7: Map showing the locations of the case study sites in Zimbabwe

Financial and Economic Analysis

The rehabilitation works were funded through grants. The estimated cost for restoring milling and electricity at the Svinurai scheme was US$9,296 including the co-operative's contribution. The grants were negotiated by ITDG in close liaison with the community. The Svinurai community contributed all the labour for the rehabilitation of the civil works, penstock and powerhouse, including the installation of a new mill. African Development Foundation (ADF) funded the irrigation component including management support and training. Funds for the first and second stage rehabilitation were secured from the States of Guernsey. For the electrification component funds were secured from a grant raised through an individual's cycling trip around Zimbabwe.

Calculations were based on a twenty-five year life expectancy. The tariff for a hydro milling service is set per bucket of milled grain. No rigorous analysis has been done on the tariff but the revenue generated has been shown to meet the operation, maintenance and management costs. An analysis of the co-operative's books shows that the mill is not regarded as a stand-alone enterprise. There is evidence that costs incurred on other farm activities are financed from the mill income while records show that operation, maintenance and repairs of the hydro mill are only financed from the mill income. Milling tariffs are set from a social standpoint and are generally below those of competing diesel fuelled mills. Income from the mill has not been consistent over the years and this can be attributed to various factors, chief of which is the lack of target-oriented management.

The financial analysis shows that if tariffs are constant in current terms over the life time of the project there is a very good return, 48% in current currency and 20% in constant dollars. We have assumed that the capital is borrowed from a renewable energy fund such as the UNDG-GEF Solar fund. This demonstrates once more the issue of services pricing.

4.1.3 Site 3: Elias Mill - A Private Micro Hydro Scheme (Mozambique)

Village Overview

This mill is in the Manica District of Mozambique, within 16km of Manica town. The main focus of the Elias plant is hydro milling. There has been no extension of the enterprise to other end-uses. Electricity generation from this plant is possible but as the houses are scattered, the number of beneficiaries may be very limited. The owner could however, install a pico-hydro plant for use at the mill and homestead. Such a generator would provide electricity for lighting, communication and small-scale enterprises.

Elias mill is an old scheme using an old pelton turbine to drive a rudimentary mill. The powerhouse is a simple timber off-cut structure thatched with grass. The Portuguese first installed this equipment around the 1930s at a different site. Mr Elias later acquired the equipment from them and installed it at his homestead. The capacity of this scheme is about 15 kW.

Project Overview

This scheme was identified by a Mozambican non-governmental organisation, Kwazai Simukai (KSM), who invited ITDG to provide them with the technical skills for the mill's rehabilitation. Up until 1999 the owner did most of the work on repairs following advice from ITDG. KSM is close to the site and, as such, does most of the follow-up. In addition KSM's in-house staff received intensive training on feasibility studies of micro hydro schemes from ITDG and turbine manufacturing from Water Energy and Development Services (WEDS) - a small Zimbabwean consultancy Company. The main funder of KSM has been exploring the possibility of Elias receiving credit assistance for components that have to be bought and involve large amounts of money relative to the monthly income from the mill. These include cement, the penstock, turbine and mill. The owner has already accepted the working arrangement, and manufacture of the turbine is already at an advanced stage. This is being done by local technicians with technical support from WEDS of Zimbabwe.

The owner runs this scheme with assistance from his family. In fact it is run as a family business and no payments are made to any associated family labour contributions. In some rare situations external labour is hired, for example when major repairs on the civil works are necessary. This labour is paid from family income without regard to whether the money was generated from the mill or not. Family members interviewed indicated that they were very comfortable with this situation. Their motivation seems to be driven by a strong household head committed to the well being of the family. This mill serves about 300 households mainly from Ndirire village[82].

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[82] Funding Proposal for Three Micro Hydro Schemes in Mozambique, ITDG, 1996.

The mill operates an average eight hours per day six days a week. In emergencies it opens briefly on the seventh day. Routine maintenance is done especially on greasing and replacing bearings, belts and cleaning the intake, channel and forebay.

Table A-26: Elias Mill Scheme Profile (US$Current)

Capacity of MHP:	15 kW
Start Date:	1996
Total Capital Cost:	US$18,000
Grant:	US$10,000
Hours of usage per day:	8 hours
Cost per installed kW:	US$1,200

Financial and Economic Analysis

In 1996 the estimated cost of rehabilitating the power plant was US$16,000 (£10,000), excluding training, monitoring, evaluation, administrative overheads and contributions by the owner[83]. Part of the funding for ITDG's technical input on the first stage of rehabilitation was provided by Andersen Consulting, UK. A grant secured by KSM from FOS-Belgium financed designs of the turbine and a training course leading to the production of a prototype. The total amount on this grant was estimated at US$8,000.

The income and expenditure of this mill was monitored over a month. This data was used to extrapolate to 25 years guided by some basic assumptions on external factors and on the performance of the mill[84]. Our calculations show an internal rate of return of 9% assuming that the capital is borrowed at an annual interest rate of 15% over the repayment period. It is assumed that the turbine currently being fabricated will be installed in 1999 and the mill will be replaced the same year. It is also assumed that the civil works will be rehabilitated in 2000.

4.1.4 Site 4: Chitofu Mill (Mozambique)

Village Overview

The Chitofu hydro mill is in the Manica District of Mozambique, within 18km of Manica town. The owner runs this scheme with assistance from his family. The mill has served a community of over 100 households with an average of six members for over sixty years. These come from two villages, namely Maridza and Nyaronga, where the alternative mill is powered by a diesel engine and charges up to 50% more than the Chitofu mill. Poorer people get the service on credit ad sometimes on barter. The owner sets tariffs for the Chitofu mill, driven by both social and business objectives. It is evident that the deployment of resources on operation and maintenance has been kept at a level just high enough for minor repairs.

Project Overview

This is an old scheme using an old pelton turbine to drive a mill. The powerhouse is a simple brick structure with corrugated iron roofing. The scheme has a capacity of about 15 kW. The owner used his own resources to develop the plant but has been getting assistance form ITDG and KSM to rehabilitate it[85.]

[83] These costs were estimated at US$2,000 according to interviews with the owner and ITDG records.
[84] A Project for Rehabilitation of Two Micro Hydro Plants in Mozambique, G Goncalves, 1998.
[85] Mini Project Proposal, Nyaronga –Chitofu, ITDG, 1995.

Like the Chitofu mill this scheme was identified by KSM who invited ITDG to provide technical skills and financial assistance for its rehabilitation. The memorandum of understanding signed in 1995 also governed the co-operation between KSM and ITDG on this project. The owner has done most of the work on repairs following advice form ITDG. The first task done was the replacement of the old-worn out bearings with new ones. At the same time some repairs were done to the old mill and penstock. A second stage involved repairs to the channel, forebay tank, penstock, powerhouse and replacement of the old mill with a new one. The owner provided labour for all the rehabilitation work. KSM continues to provide most of the follow-up because of its proximity to the project site.

As in the case of the Elias mill, the local authority under which the scheme falls had not been involved in the planning or implementation of the rehabilitation work. The mill operates an average eight hours per day, six days per week, but in emergencies it opens briefly on the seventh day. Routine maintenance is done especially on greasing and replacing bearings, replacing belts and cleaning the intake, channel and forebay.

The main focus of the Chitofu plant is hydro milling. There has been no extension of the enterprise to other end-uses. Current efforts are to improve this service but there is potential to use the same plant to generate electricity. This would be a very attractive option considering that within 600 m of the plant there is a school, clustered houses and a business centre. Small-scale industries could also surface provided other conditions such as finance and training are attractive.

Table A-27: Chitofu Mill Scheme Profile (US$1996)

Capacity of MHP:	15 kW
Start Date:	1995
Total Capital Cost:	US$18,500
End-use:	Grain milling
Hours of household usage per day	8
Cost per installed kW	US$1,233

Financial Analysis

A combination of grants and owner finance has been used to rehabilitate the scheme. Estimates for rehabilitation of this mill were done at the same time as for Elias, and a figure of US$16,000 (£10,000) was reached. This excludes training, monitoring, evaluation, administrative overheads and contributions by the owner[86]. The core funding for this project was a grant secured by ITDG from Andersen Consulting and the DFID of the United Kingdom. These funds covered materials for repair to the powerhouse, the turbine housing and replacement of bearings, repairs to the old mill and its eventual replacement and the technical inputs by ITDG. Chitofu contributed labour during the repairs. The owner also provided labour for repairs to the intake works, canal, forebay tank and penstock.

No systematic monitoring of income and expenditure has been done on this scheme. Historical data has been generated through interviews with the members of the family responsible for milling. Our calculations show an internal rate of return of 9%,

[86] Estimated at US$2,500 from interviews with owner and ITDG's records.

assuming that the capital is borrowed at an annual interest rate of 15% over the repayment period.

Figure A-8: Map showing the locations of the case study sites in Mozambique

4.2 Summary of Findings of Micro Level Analysis

Significant effort has been made by NGOs working with various stakeholders to demonstrate that micro hydro can supply much needed energy to remote rural communities. The four cases selected for Zimbabwe and Mozambique are a clear demonstration of the technical viability of hydro as an alternative energy source and can, therefore, be replicated with relative ease. Management of such schemes appears to be within the grasp of the ordinary rural farmers. Moreover, their capabilities can be extended with additional training, and personnel should only need to be brought in in exceptional cases where system failures are experienced. The only apparent constraints concern financial management, particularly regarding the approach taken on tariff setting. All four schemes need to improve on the utilisation of the available power. This can in turn improve on the returns from the investment.

A point of concern, however, is the cost involved in micro hydro technology. The cost is prohibitive particularly for rural productive operations, which often have low output due to the demand conditions that prevail in the rural areas. The technology lends itself well to variations in scale thus allowing different size systems to be installed to suit particular needs or particular resource potentials.

In both Zimbabwe and Mozambique lack of energy planning at the local and regional levels can be attributed in part to lack of awareness on energy options available at that level. This highlights the fact that energy provision has not yet been recognised as an integral part of the development process that needs to be planned for. The tendency is to regard the national grid as the only energy source of electricity. This is only supplied by utilities, and at the local level electrical power has tended to be synonymous with the utilities.

The process of getting information from the rural communities on local resources and development needs could also be improved to allow for better planning that would, hopefully, incorporate energy issues. Embarking on community empowerment exercises that would give communities an insight into their role in the development of their ward or district could further facilitate this.

The environmental impacts of the four micro hydro schemes selected for this study can be classified as minor according to Zimbabwe's guidelines on environmental impact assessment.

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