LOW COST

ELECTRICITY INSTALLATION

By

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FOREWORD

This report was initiated and funded by the Overseas Development Administration (ODA) and was written by Dr Nigel Smith. Dr Smith is an independent engineering consultant with experience in low cost electrification in developing countries.

The report starts from the observation that in most developing countries efforts to provide electricity to poor households have had only limited success. The purpose of this report is to:

- Provide in a single reference document a review of the problems faced by poorer users and potential users and the constraints faced by power utilities.
- Identify possible technical solutions existing or under development.
- Identify how such solutions might be implemented through modified policy standards, training/technology transfer and hardware development.
- Identify possible areas for monitoring the performance of existing systems or field trials of new developments.

This report provides an overview of the problems and recommends some appropriate solutions. This has been achieved by a literature search, contacts and interviews with a variety of experts (see Appendices 2 and 3) and visits to six developing countries. The report addresses the problems faced by low income users and potential users with access to electricity, including house-wiring costs. Hence, the use of the term installation rather than connection in the title of the report. The problems associated with providing electricity to poor households which are a long distance from the electricity supply are not covered in this study.

The report suggests a number of new approaches which can make electrification more economic for the utility, and spread the benefits of electrification more equitably across the social spectrum.

Ray Holland,

Managing Director, Intermediate Technology Consultants

1 EXECUTIVE SUMMARY

This study addresses the causes of low rates of electricity connection amongst low income households who have access to electricity. It covers the problems of high connection costs, high costs of house-wiring, and housing failing to meet the standard required. It also addresses the constraints faced by the electricity utilities, including high capital costs and high revenue collection costs. The problems associated with providing electricity to poor households who are a long distance from the electricity supply are not covered in this study.

An overview of the problems was obtained by a literature search and more detailed information was gained by contacting experts and making visits to six developing countries. The report provides an overview of the problems and recommends solutions. The solutions include load limited supplies, prepayment meters, pre-fabricated wiring systems, revised safety standards, credit systems, community involvement and tariff reforms.

The following are the main conclusions of this study:

- Special approaches are required if connections to low income households are to be economic. Many households, particularly in rural areas, cannot afford to spend even $3 per month on electricity. In subsistence farming communities the average expenditure by electrified households can be less than $1 per month.
- The electricity consumption of low income households is often just a few tens of kilowatt hours per month.
- The main problems faced by low income households in obtaining an electricity supply are high initial connection charges and high costs of house-wiring.
- High energy charges are not a major cause of low rates of connection of poor households, as kerosene for lighting and batteries for radios are very costly alternatives. However, high fixed or standing charges are an appreciable deterrent, as in some cases they are higher than the total amount that households can afford to spend on electricity.
- The high costs faced by new consumers can be reduced by involving local people in the installation work and through the use of pre-fabricated house-wiring systems such as wiring harnesses and 'Ready Boards'.

- When credit for connection costs and house-wiring is made available, much higher rates of connection are usually achieved amongst low income households.
- Electricity regulations often prevent the poorest households from obtaining a supply by forbidding connection to thatched roofed houses. With appropriate techniques, such houses can be connected with a high degree of safety and the dangers will be less than those associated with using kerosene and candles.
- The main dangers with providing electricity to low income households are electric shock and fire resulting from unsafe extensions to house-wiring. These dangers can be reduced by the use of earth leakage circuit breakers, flexible wiring systems, education and regular safety checks.
- The per customer capital cost incurred by the utility is less when low income households are connected, due to their lower power consumption. It is further reduced when load limited supplies are used.
- Billing and revenue collection costs can be reduced substantially by installing load limiters instead of meters and in some cases by community collection of payments. These cost reductions are essential if households with very low electricity consumption are to be supplied economically.
- Prepayment meters are suitable for consumers with levels of electricity consumption in excess of 100 kWh per month. This can include lower income households in areas where electricity is the most cost-effective cooking fuel.
- There is little communication between electricity utilities regarding the problem of providing electricity to low income households. This could be addressed by establishing a network to enable those involved to learn from each others experieinces.

2 BACKGROUND

2.1 UPTAKE OF ELECTRICITY CONNECTIONS BY LOW INCOME HOUSEHOLDS

There are two main reasons why low income households may not have electricity. The first is that there is no possibility of obtaining a connection, as they are much too far from a supply. The second is that they have access to electricity but cannot afford the cost of electricity installation. It is this second problem that is addressed in this report.

The lowest rates of electricity adoption tend to occur in rural areas. For example, in the rural areas of Zimbabwe where electricity is available only about 6% of households have a connection (SEI/BUN, 1993). In contrast, the connection rate in urban areas is approximately 90% (Rafemoyo, 1994). The main reason for this is the higher disposable income of urban households. In the case of Zimbabwe, as a result of large subsidies for rural electrification, the connection fee is the same for rural and urban households. If the true costs of the electrification project were passed on to the consumers the adoption rate in rural areas would be even lower.

2.2 REASONS FOR PROVIDING ELECTRICITY TO LOW INCOME HOUSEHOLDS

Electricity is highly desired by low income households but is all too often only obtained by the richer people in developing countries. The tremendous sacrifices and high payments that low income households are often prepared to make to obtain even small amounts of electricity indicate the importance that they attach to it.

A wide range of benefits can result from providing electricity to low income households (Foley, 1990. Nafziger, 1994. Wasserman and Davenport, 1983). Often the main benefit is improved lighting, as high quality light facilitates a wide variety of socially and economically beneficial activities. A study in Peru shows that electric lighting can produce a dramatic rise in living standards:

> *"...electricity enables them to sew, spin, knit, separate seeds, etc. - activities which only have been accomplished earlier with great effort under the light of a kerosene lamp or a candle"* (Valencia and Seppanen, 1987).

However, provision of electricity does not always increase income generation, as shown in a study in Bangladesh:

> *"Electricity enables more baskets to be woven at night, but not more baskets to be sold by day"* (Uddin, 1989).

The introduction of electricity does not automatically stimulate economic growth. Its effect is dependant upon a number of complementary factors, including the level of development in the area, the availability of capital and other resources and access to markets (Foley, 1990).

> *"Unless the other necessary infrastructural elements and the proper conditions for economic development are already present, rural electrification will not, by itself, cause an area to develop. When the necessary conditions for economic take-off are present, however, experience shows that the provision of a reliable electricity supply can act as a stimulus to economic development."* (SEI/BUN, 1993).

Electricity generally produces a greater improvement in lighting for lower income households than richer households, as they cannot afford as much lighting from kerosene and candles. One kilowatt hour (kWh) of electricity used in a 60 W electric light-bulb produces the same amount of light as about 12 litres of kerosene burned in a kerosene lantern, which, at typical prices, makes electric lighting about 100 times cheaper than kerosene lighting (Foley, 1990).

Mains electricity is a much cheaper power source for radios than batteries. Typical battery costs are $100/kWh for dry cells and $1/kWh for well maintained car batteries that are never deeply discharged (Louineau et al, 1994). In the case of car batteries, the cost of recharging must be taken into account. In Sri Lanka this is typically $0.65 per charge, excluding any transport costs (Hettiaratchi and Brown, 1991).

Households can make significant financial savings on energy expenditure when they obtain mains electricity. A recent study in Bolivia notes the following comment from a villager in the town of Vacas:

> *"Electricity is very important and is cheaper besides. Here in Vacas my aunt and uncle pay Bs 15 (US$3.75) each month and we in the countryside spend Bs 30 on candles, Bs 14 on gas for the lamp and Bs 15 for radio batteries. That's a total of nearly Bs 60 (US$15) each month."* (NRECA, 1993).

However, in some studies, the expenditure on lighting has been found to increase after electrification. This is due to either a significant increase in the use of lights and increased illumination levels or high fixed monthly charges for electricity. For example, a study in rural Indonesia notes that:

> *"Of all the households using electricity for lighting alone, 96 percent increased the proportion of their expenditures allocated to lighting"* (Brodman, 1982).

Whilst household expenditure on lighting may or may not increase for low income households that obtain electricity, there is no uncertainty regarding the improved illumination levels. Electric lighting makes it easier for children to study in the evenings. This is a particular benefit to low income households as they are unlikely to be able to afford the cost of lighting, for this purpose, from other energy sources. A recent study in Bolivia (NRECA, 1993) notes the following comments from beneficiaries in the town of Vacas:

> *"Now the children study at night and during the day they can help at home."*

> *"Before the area was electrified, Vacas was quite empty, deserted. Now the school has improved greatly and it is possible to have night school for adults."*

In some circumstances the provision of electricity to low income households will reduce their consumption of wood. Where wood can be gathered without payment, poor households often use it as their only, or main, source of lighting. Indeed a factor against the use of more efficient and enclosed cooking stoves has been the need for light, and this has caused difficulties for many improved wood stove programmes (Louineau et al, 1994). Data from Ethiopia indicates that in 1984 lighting accounted for 15.3% of total fuelwood consumption (AFREPEN, 1992). This is a major concern in a country where deforestation is already a problem. However, reduced wood consumption is only likely in warm climates, as in cold climates good quality lighting may encourage households to stay up later in the evenings and burn more wood for warmth.

2.3 ELECTRICITY USAGE BY LOW INCOME HOUSEHOLDS

The poorest households use electricity for just one or two light-bulbs. Those with slightly higher incomes use more lights and low cost, low power consumption appliances such as radios and fans (Barnes, 1988. Nafziger, 1994). The electricity consumption of these low income households is extremely low. For example, at the

Andhi Khola electrification project in Nepal, the average demand by rural consumers is less than 100 W per household. Here, the consumers are offered a load limited supply of 25 W, 50 W or 250 W. The average monthly energy consumption figures for each of these tariff categories are 6 kWh, 12 kWh and 67 kWh respectively. More than two thirds of rural users subscribe to the 50 W supply and use just one or two light-bulbs and a radio (Nafziger, 1994). Similar levels of consumption occur on micro-hydro projects in Indonesia and Sri Lanka, and in village electrification projects on the Pacific Islands (Herrmann, 1990).

Electricity usage is generally higher in urban areas than rural areas as cash incomes are higher. In a few countries, such as Laos, there are some urban areas where electricity is the cheapest cooking fuel and, as a result, even the lower income households consume relatively large amounts of electricity.

The electricity usage of low income households is often overestimated by the utilities. ESKOM in South Africa have encountered this with their township electrification projects:

> *"Our experience is that we tend to overestimate consumption and overdesign the distribution system. This leads not only to unnecessary high capital investment, but also causes high losses in transformer cores, leading to harmonic problems which we first detected when our pre-paid meters started malfunctioning. ......it can be seen that even in a high density urban area an overdesign based on an estimated 3 kVA After-Diversity Maximum Demand (ADMD) would cost almost 60% more than a design based on 1 kVA ADMD."* (Engelbrecht, 1994)

In low density urban or rural areas the cost increase resulting from an overdesign of the distribution system will be higher than for high density urban areas because distribution costs are more significant.

If the connection of low income households is to be financially viable then special approaches are required to address the problem of low revenue caused by very low levels of consumption. Such approaches are outlined in Chapter 6 of this report.

3 FINANCIAL VIABILITY

3.1 EXPENDITURE ON ELECTRICITY BY LOW INCOME HOUSEHOLDS

A recent World Bank study found that the percentage of household income spent on electricity by urban households is about three percent of total income, regardless of income class (World Bank, 1994). This was a comprehensive investigation, involving data collection from almost 20,000 households in 45 cities and 12 countries.

For the purpose of this study, a low income household will be defined as one which will spend less than $3 per month on electricity. For urban households, this corresponds to a total monthly income of less than $100 per month. In the poorer developing countries a high proportion of urban households will be considered low income, whereas in the richer developing countries this proportion will be quite low.

An example of electricity expenditures is given in Table 1, which presents data for an urban area in Zimbabwe, a middle-income developing country. Nearly 85% of households pay more than $3 per month for an electricity supply.

Tariff Category	Number of connections	Monthly charge (US$)
No supply	4,163	None
1 Amp load limiter	708	2.46
2.5 Amp load limiter	73	3.30
5 Amp load limiter	6,247	5.15
7.5 Amp load limiter	4,800	8.19
Metered supply	14,862	2.27 + 0.023 / kWh*

Table 1 Distribution of urban consumers according to tariff category at Chitungwiza, Zimbabwe (Rafemoyo, 1994).

*$0.034 / kWh after first 300 kWh.

Expenditure on electricity is much lower in rural areas than urban areas and therefore a higher percentage of households are in the low income category. This is well illustrated by an example from Nepal. At the Andhi Khola electrification project electricity is supplied to both rural and semi-urban consumers, with more than 95% of households having a connection. It is clear from Table 2 that the rural consumers generally subscribe to the 25 W and 50 W load limited supplies, whereas the semi-urban consumers tend to have a 250 W load limiter or meter. The monthly cost for the load limited supplies are $0.34 for 25 W, $0.70 for 50 W and $1.90 for 250 W. The average monthly consumption of the metered consumers is 87 kWh at a cost of $3.70 (Nafziger, 1994).

Type of consumer	Load limited consumer			Metered consumer	Total
	25W	50W	250W		
Rural	19	127	40	0	186
Semi-urban	2	59	171	83	315

Table 2 Distribution of domestic consumers according to type and tariff category at Andhi Khola, Nepal (Nafziger 1994).

Approximately 80% of the semi-urban households are low income households as their expenditure on electricity is less than $3 per month. All of the rural households are in the low income category, and the majority spend less than $1 per month on electricity.

3.2 THE COST TO THE UTILITY OF PROVIDING ELECTRICITY TO DOMESTIC CONSUMERS

In order to determine how the cost of supplying electricity to low income households can be reduced, it is necessary to examine all the financial aspects of electricity provision. The cost to the utility of providing electricity to domestic consumers can be split into three basic components (Herrmann, 1990):

- Maximum demand related costs
- Energy related costs
- Consumer related costs

Maximum Demand Related Costs

These are the fixed costs related to the maximum load that the consumers jointly impose on the system. They are the costs of the generating plant, transmission and distribution, but not the consumer's service connection. They include the purchase, installation, financing and eventual replacement of this equipment. They also include the fixed maintenance costs, i.e. those that are time rather than energy related.

Energy Related Costs

These are the variable costs related to the production of energy and the delivery of energy to the consumer. The energy related costs are highly dependant upon the type of primary energy used for generation. For example, they are very high in the case of diesel generation and very low in the case of hydro generation. They include the maintenance costs which are output related.

There are also energy related costs resulting from the delivery of electricity to the consumer, as energy losses in power lines and transformers are dependant upon the energy transferred.

Consumer Related Costs

These are the fixed costs related to the number of consumers, their location, density and whether they have a metered or unmetered supply. They include the provision and maintenance of the service connection, i.e. the connection from the distribution line to the individual consumer, and the cost of any metering and house-wiring provided by the utility. Where a connection fee is charged, this should be offset against the cost of the service connection.

The consumer related costs also include revenue collection, accounting, and dealing with complaints and queries. In the case of a metered connection this will include meter reading, billing and collection, whereas with a load limited supply no meter reading and billing are required.

Average Utility Costs

Maximum demand related costs are very large due to the very high capital costs of electrification infrastructure. The costs are particularly high for rural electrification projects. A World Bank report gives an average cost per connection of $750, in 1987 prices, for the distribution system alone (World Bank, 1990).

Recent data for township electrification projects in South Africa gives an average cost of approximately R 3,000 ($800) per consumer (Engelbrecht, 1994). This includes the cost of a prepayment meter and a 'Ready Board' (described in Chapter 6) as well as the distribution system. In order for the utility, ESKOM, to recover the installation cost, with interest, over 15 years and cover the operating costs, there must be a net monthly income of R 48. The consumer is charged R 0.218/kWh and the energy related cost is R 0.134/kWh. In order for ESKOM to break even the consumer must use 570 kWh per month at a cost of R 125 ($33), as shown in Figure 1.

Most of the costs for these township projects are lower than for other electrification projects, especially those serving rural areas, due to the high density of consumers and mass electrification programme. Hence, it is clear that the average cost of a metered connection is very high. It can be higher than the per capita GNP of many countries and many times higher than low income households are able or willing to pay, as discussed in Section 3.1. If electricity utilities in developing countries are to operate without subsidy and supply the majority of the population then the cost of connecting low income households must be much less than the average cost of a metered supply from the grid.

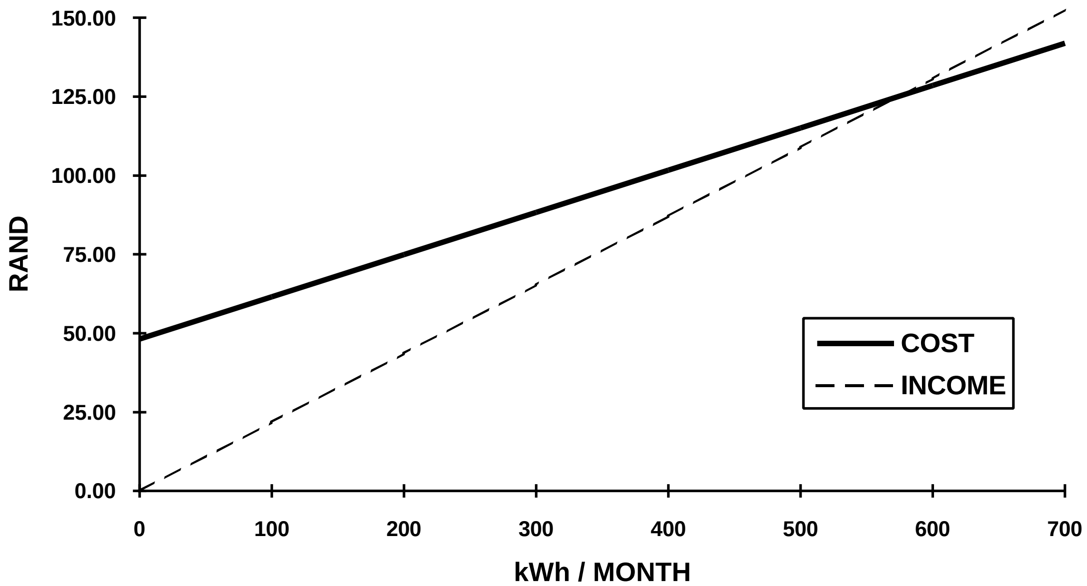

Figure 1 Income and cost against energy usage for ESKOM township electrification projects (Engelbrecht, 1994).

3.3 REDUCING THE COST TO THE UTILITY OF PROVIDING ELECTRICITY TO LOW INCOME HOUSEHOLDS

The cost components of providing electricity to domestic consumers were set out in Section 3.2. For a given electrification scheme, the costs per household will vary according to the level of electricity consumption and the type of connection provided. This section examines these costs and how they can be reduced when providing electricity to low income households.

Maximum Demand Related Costs

Low income households consume relatively small amounts of electricity primarily for lighting, as described in Section 2.3. Assuming an electricity price of $0.06 / kWh and using the definition of a low income household given in Section 3.1, low income households consume less than 50 kWh per month. If electricity is used for just five hours per day the average consumption during this period will be less than 330 W. The maximum demand can be kept close to this level by means of a load limiter, as explained in Section 6.1.

Richer households who use electricity for cookers, water heaters and other high power consumption appliances can easily have a maximum demand ten times higher than a low income household. Hence, the maximum demand related costs are considerably lower for supplying low income households. Though these cost savings will only be fully achieved if the lower demand of low income households is taken into account when designing the transmission and distribution system.

At the Andhi Khola project in Nepal, mentioned in Section 3.1, all the rural households are provided with load limited supplies in order to reduce the peak demand. This has enabled 1 kV rather than 11 kV distribution to be used and groups of four or five houses are served by 1000 V / 230 V transformers of 1 kVA rating. The cost of the distribution to the 167 consumers in the village of Aserdi, shown in Figure 2, was approximately $150 per household (Mackay, 1990). This is about 20% of the typical cost of rural distribution presented in Section 3.2.

Maximum demand related costs will be lower in urban areas than rural areas due to the reduced costs of transmission and distribution.

Figure 2 1 kV distribution at Aserdi, Nepal (Mackay, 1990).

Energy Related Costs

The connection of low income households to the supply will generally have little effect on energy related costs, because the increase in energy consumption will be small. The use of load limiters, as suggested in the previous sub-section will help to improve load factor, as described in Chapter 6, and could produce a marginal decrease in average energy related costs.

Low income households can afford to pay high energy related costs for electricity when this results in savings on kerosene, candles and batteries, as explained in Section 2.2. High energy charges do little to deter low income households from taking an electricity supply, though they do have a significant effect upon the level of consumption (World Bank, 1994).

Consumer Related Costs

The main elements of the consumer related costs are:

- Service connection and meter
- Revenue collection

The cost of the service connection is highly dependant upon the distance from the consumer to the distribution line. The cost of a service connection to houses that are close to low voltage overhead lines can be very low.

In India the Rural Electrification Corporation (REC) funds hundreds of thousands of connections to low income households each year under its 'Kutir Jyothi' (illumination of the hut) programme. Payments of Rs 470 ($15) per connection are provided to State Electricity Boards to pay for the costs, including installation, of the service connection, earth and one light fitting and 40 W light-bulb per household (Sen Gupta, 1994). No meter or load limiter is installed, just fuses to protect the wiring. The cost of an Indian meter or a load limiter would increase the cost, though to less than $30. Each household pays a fixed charge to the electricity board of just Rs 5.1 ($0.17) per month.

This example indicates the very low cost of providing a service connection that can be achieved when the houses are very close to low voltage distribution lines. The costs are realistic as in many cases the electricity boards use private contractors to do the work for the same payment as that provided by the REC.

However, where a low income household is a long way from the distribution line, the service connection will be very expensive and this alone will make it unprofitable for the utility to provide the connection unless the consumer pays the extra cost.

The cost of revenue collection is very significant for supplies to low income households who use very little electricity. Costs vary widely, depending on density of consumers, staff costs and efficiency, as shown in Section 4.2. The costs are generally within the range $0.10 and $0.50 per month for a metered supply. If electricity utilities are to cover their costs when supplying households with low levels of electricity consumption, they must pass this charge on to the consumer. This is generally achieved through a monthly fixed charge, which is may be too high for some low income households to afford.

Revenue collection costs can be reduced substantially by using load limiters instead of meters and, where possible, community involvement in revenue collection. These solutions are described in more detail in Chapter 6. These two approaches, when used together can result in monthly revenue collection costs of just a few cents per month.

Conclusions

The cost to the utility of providing an electricity supply is much less for low income households than for high income households, especially if their low maximum demand is taken into account when sizing the transmission and distribution system. It can be further reduced by means of load limiters, which, in addition to reducing the capital cost by reducing peak demand, reduce the recurrent cost by enabling savings on revenue collection to be made.

4 CONSTRAINTS FACED BY UTILITIES

For governments in most developing countries, making electricity available to a large percentage of the population is an important goal. The utility companies however, whether state owned or with a degree of independence, have severe problems in meeting this goal. The main constraints that they face are discussed below.

4.1 HIGH CAPITAL COSTS

A major constraint faced by electricity utilities is the need to recoup the capital costs of generating plant, and transmission and distribution networks. Passing on all or some of these costs to the consumer in the form of a 'connection charge' is very attractive to the utility as it provides them with an immediate income. However, a large connection charge will deter a low income household from obtaining a connection.

The cost of providing electricity to low income households can be reduced by using the approaches outlined in Section 3.3. When carefully implemented these approaches will allow more households to be connected to the supply and provide a net financial contribution to the utility.

4.2 HIGH REVENUE COLLECTION COSTS

Utilities tend to find that for low income households, which only consume a small amount of electricity, the costs of meter reading, billing, revenue collection and administration outweigh the revenue collected. This is without considering the costs of generating the electricity, maintaining the network or the initial capital costs.

Cost estimates for monthly meter reading, billing, collection and accounting expenses vary widely. For meter reading alone, the per customer costs in more populated rural areas range from $0.03 in Bangladesh and parts of Guatemala to $0.15 and above in Costa Rica and El Salvador (Inversin, 1994). When bill preparation and serving charges and overheads are taken into account, the total cost of meter reading, billing, collection and accounting is approximately three and a half times the basic meter reading cost (Krishna Rao, 1994). Hence, the total cost ranges from $0.10 to more than $0.50 in more populated rural areas. The cost will generally be lower in urban areas and higher in less populated rural areas.

Revenue collection costs can be reduced by households with a metered connection supplying electricity to nearby households, either legally or illegally. In Bangladesh such sub-connections are allowed and it is estimated that an average of 2.5 families are supplied by each meter (Foley, 1990). However, this can lead to exploitation of the sub-connected, and usually poorer, households by the metered consumer charging excessive amounts for the electricity supplied. This has been observed in Nepal (Nafziger, 1990). A further disadvantage of sub-connections is that the electrical installation to the unmetered households is rarely checked by the utility. There are safer and less potentially exploitative ways of reducing revenue collection costs, as described in Chapter 6.

4.3 LOW INCOME FROM EXISTING OPERATION

In many cases utilities are fettered by the amount they are allowed to charge for electricity.

> *"Most utilities also find that their tariff systems are so heavily constrained by historical and political factors that their room for manoeuvre on electricity prices is extremely limited. In the majority of cases, tariff policy tends to be a pragmatic and often uneasy compromise between a variety of conflicting pressures."* (Foley, 1990).

Low income due to low tariffs generally necessitates reductions in operation and maintenance costs and system upgrades. These in turn lead to a poorer quality supply and a reduction in revenue. The customers are unwilling to accept tariff increases when the supply is of poor quality and as a result the situation gets progressively worse.

Electricity boards often face the additional problem of being forced by government to provide electricity to certain places or, in some cases, to poor households. State authorities can also interfere with revenue collection. For example, The Karnataka Electricity Board in India is forbidden by the state government from disconnecting customers on the lifeline or 'Kutir Jyothi' tariff who default on payments. As a result, very few of these customers pay their bills.

Poor cash flow due to late payment of bills compounds the problem of low tariffs. In Nigeria the average electricity bill is more than a year old (World Bank/IFC 1994). Often government departments are amongst the worst defaulters on payments.

4.4 INSUFFICIENT GENERATING CAPACITY FOR ADDITIONAL CONSUMERS

Electricity utilities in developing countries often have insufficient capacity to supply existing consumers, let alone new ones. The problem is well dealt with in other sources and will not be discussed in this report. The solutions include tariff reforms, better power sector planning, private participation, improved maintenance of generating plant, and efficiency improvements. Poor load factor is a major problem in some countries and can be improved by demand side management.

4.5 HIGH CONNECTION COSTS TO SCATTERED HOMESTEADS

The provision of long distribution lines to individual homes is expensive. If the home is a low income household, electricity connection is likely to be unprofitable in all circumstances. The provision of self-contained electricity generation packages for individual households, using solar cells may provide a solution in the long term. However, these are expensive at present and are beyond the reach of low income households. The problem of supplying isolated low income households will not be considered further here.

4.6 THEFT

A problem faced by utility companies is that electricity is stolen by illegal connection to the supply and by the bypassing of meters and load limiters. This impacts upon the income received by the utility and reduces the return on investment. Theft of equipment is an additional problem in some countries and can include such large items as distribution cables and pylon supports.

5 PROBLEMS FACED BY CONSUMERS

5.1 HIGH CHARGE FOR INITIAL CONNECTION

A major constraint faced by a low income household is the high cost of obtaining a connection. The utilities impose high costs in order to recoup some or all of their investment in the electrification project. In some cases the charges are kept high in order to deter low income households from obtaining a connection, because, as explained in Chapter 4, it may not be financially viable to supply them.

There is considerable variation in connection charges between, and sometimes within countries. Charges range from less than $20 to over $4,000. The highest costs occur where all or part of the cost of the distribution transformer is included in the cost of the connection. This is particularly the case in rural Africa where scattered homesteads mean that several distribution transformers are required for each village (Kandawire, 1992, AFREPEN, 1992).

Households in rural areas often have particular problems in raising cash and may have to sell land or livestock in order to afford the connection charges.

5.2 HIGH COST OF HOUSE-WIRING

House-wiring can be very expensive and in many cases is more than the connection fee. For example, figures from Malawi indicate that house-wiring for a low income household costs in excess of $100, which is more than ten times the fee paid to the utility for the connection (Kandawire, 1992).

Conventional house-wiring is easy and neat for houses with concrete or cement-plastered brick walls. However, for houses built from bamboo or other flexible light materials or with mud and stone walls, conventional wiring is awkward due to the uneven nature of the surfaces and the difficulty of securing the wiring. This can result in high labour costs.

Electrical contractors generally charge by the quantity of material that they install and therefore often install unnecessary components (Inversin, 1994. Kandawire 1992). Costs are further increased when the electrician has to come from a long distance away.

At the Andhi Khola project in Nepal conventional wiring costs at least $30. Alternative, pre-fabricated wiring systems have been developed that are less than one sixth of this price. These are discussed in Section 6.3.

5.3 UNCERTAINTY OVER ELECTRICITY CHARGES

Uncertainty over electricity charges particularly affects low income households as they have to budget their money very carefully. Some utilities have a confusing range of tariffs. Others, especially where inflation is high, have charges that are linked to the US dollar. This is sensible from the point of view of the utility but causes uncertainty and confusion for the consumer (NRECA, 1993). Some consumers are unable to read their meter and need education so that they can have more control and understanding of their electricity consumption.

5.4 SAFETY STANDARDS

The houses belonging to low-income households, particularly in rural areas, often fail to meet the minimum construction standards set by the utility. A watertight roof is often specified, and as a result thatched roofs often have to be replaced with corrugated iron sheets.

This is a problem for the Kutir Jyothi programme in India, described in Section 3.3. In some cases the local electricity boards, at their own discretion, overlook failures to meet the required standards in order to provide electricity to the poorest households. In other cases the standards are enforced and some of the poorest households are excluded from a programme that has been set up specifically for their benefit.

5.5 DISTANCE TO PAYMENT CENTRE

Particularly with rural electrification schemes, householders may have to travel many miles in order to pay their bills. As well as encouraging defaults on payments, this may discourage other potential consumers from obtaining a connection.

5.6 POOR QUALITY / RELIABILITY OF SUPPLY

Frequent voltage fluctuations and/or frequent outages can be a major source of complaint by existing consumers and a deterrent to potential consumers. These problems are generally caused by overloading and poor regulation or lack of protection against network faults and lightning.

Both overvoltages and undervoltages can damage domestic appliances. In addition, undervoltages will cause appliances to operate at reduced output and often reduced efficiency. Frequent outages can force electricity users to maintain and purchase fuel for appliances operated from other energy sources. This is the case in the Philippines:

> *"A power system with adequate capacity and reliability of service will experience no more than 7 hours of blackout per year; the Philippines experiences 750 hours."* (World Bank/IFC 1994).

6 SOLUTIONS

There are a number of solutions that can specifically help low income households to obtain an electricity connection and help utilities to meet their required return on investment. These are:

- Load limited supply
- Reduced service connection costs
- Pre-fabricated wiring systems
- Credit
- Community involvement
- Prepayment meters
- Tariff reforms
- Revised safety standards

More general solutions, which relate to the financial viability of complete projects rather than the specific issue of electricity installation for low income households, are not covered in this report. It is recognised that such solutions can have a positive impact on the number of electricity connections to low income households by increasing the rate of electrification in developing countries.

6.1 LOAD LIMITED SUPPLY

6.1.1 General description

The use of load limiters is one of the most important solutions for reducing connection and operating costs, particularly for low income households. Load limiters work by limiting the current supplied to the consumer to a prescribed value. If the current exceeds this value the device automatically disconnects the supply. Some types of load limiter must be manually reset, whilst others automatically reset when the overload is removed. The consumer is charged a fixed monthly fee (according to the load limit), irrespective of the total amount of energy consumed.

When marketing the electricity connection to householders, the word 'limiter' tends to have a negative impact. It would be better to describe the whole package as an economy or unmetered supply.

6.1.2 Basic operation

There are three types of load limiter:

- Miniature Circuit Breaker (MCB)
- Positive Temperature Coefficient Thermistor (PTC)
- Electronic Current Cut-out (ECC)

The **MCB** is the most widely used load limiter. Electrical engineers are familiar with MCBs because they are used extensively for current limiting with meters, and for overcurrent protection of electrical wiring. MCBs are mass produced, robust and low cost. The standard current range is from 1 Amp to 100 Amps.

Figure 3 1 Amp MCB type load limiter, Zimbabwe.

Figure 3 shows an MCB type load limiter used in Zimbabwe. The MCB on the left is the load limiter. The other two MCBs have been included to protect the light and socket outlets. They are only necessary if the load limiter has a higher current rating than these circuits. The unit is mounted on the outside of the customers dwelling and locked.

There are two types of sensing mechanism used in MCBs; thermal and magnetic. Some MCBs incorporate both, with thermal sensing for small overloads and magnetic sensing for high overloads or short circuits. These are called thermal-magnetic MCBs as opposed to purely thermal or purely magnetic. For the purpose of this report, they will be classified as thermal MCBs as it is the thermal sensing element that operates for load limiting. Purely magnetic types are the least common, but have the advantage of being the most accurate. When overloaded, MCBs physically disconnect the supply by releasing a pair of contacts. They have to be manually reset after the overload is cleared.

The **PTC** is a more recent development that uses semiconductor technology. PTCs are mass produced for overload protection in telecommunications and consumer goods. Until recently PTCs have not been used for domestic electricity connection. One of the main reasons for this is the low current rating - typically 20 mA to 500 mA for mains voltage types. For conventional electricity connection such a low current limit would not even be considered.

The PTC is a disc of about 15 mm diameter which is connected in series with the load. It can be installed instead of one of the links in the service connection box, as shown in Figure 4. At currents below a threshold value the PTC thermistor effectively presents a short-circuit; but if the current increases beyond this value the resistance increases sharply and effectively disconnects the load. A low residual current maintains the PTC at a high resistance until the supply is disconnected or the load removed. The device itself does not have to be physically reset. A fuse is required to provide short circuit protection.

Figure 4 PTC incorporated in connection box (external and internal views), micro hydro project, Java, Indonesia.

The **ECC** is a very recent development. This is so much so, that it is still at the field trial stage. ECCs are being developed specifically for use as load limiters. Most of the work is taking place in Nepal (Van Wijhe, 1991). The range currently being developed is for 500 mA to 3 Amps.

A simplified circuit diagram for an ECC is shown in Figure 5. With the switch, S, open, no current can pass and the load is disconnected. When the switch closes, the load is turned on, as there is a path for current through the rectifier bridge and the resistor R. The resistor, R, has a very low value to give a voltage drop of less than one volt. This voltage is an accurate measurement of the load current, and is used to turn off the electronic switch, S, if the current exceeds the rating of the ECC. The switch is a thyristor or triac. The rectifier bridge is needed to produce a d.c. voltage across R, which simplifies the control circuitry. A fast acting fuse is included for short-circuit protection.

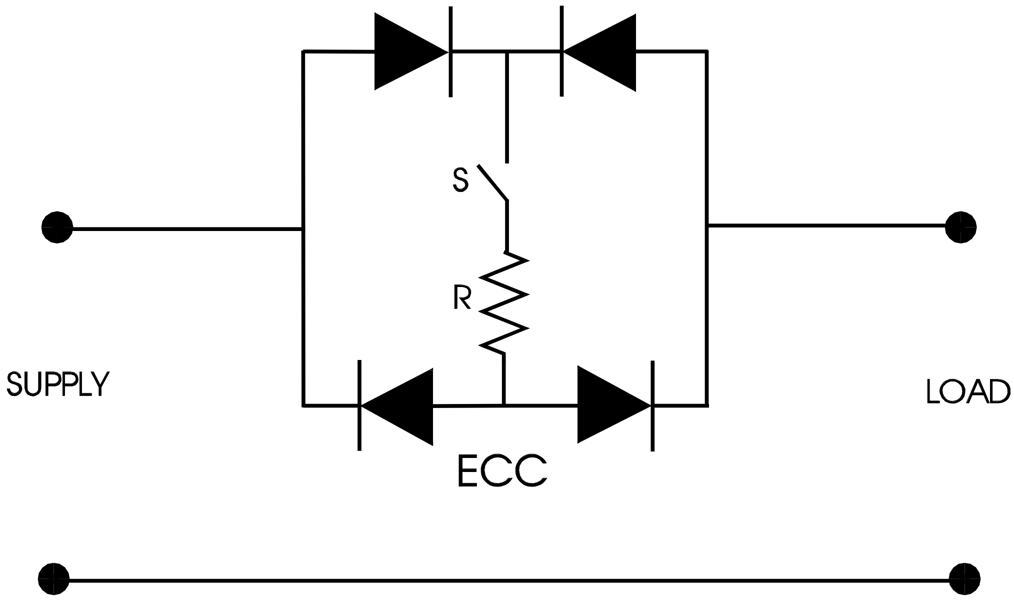

Figure 5 Simplified circuit diagram for an ECC.

6.1.3 Load factor

Load factor is the actual energy usage as a percentage of the maximum energy usage. The use of load limiters affects both the load factor of the supply, be it the grid or an isolated system, and the individual load factor of the consumer.

Load factor of the supply

Load limiters limit the maximum power that the consumer draws from the supply. Their use will help to control the maximum demand related costs, as described in Sections 3.2 and 3.3. The effect on the maximum demand related costs of adding load limited consumers will be negligible, unless such connections make up a significant part of the load.

On new electrification projects incorporating load limited connections, immediate savings can be made through smaller transformers and reduced cable sizes or lower voltage transmission. These savings are most significant for rural electrification projects with their high per customer transmission and distribution costs, as discussed in Section 3.3.

With isolated generating systems, load limiters can result in very significant savings in the cost of generating equipment. They are used on a number of mini and micro hydro schemes in Indonesia, Nepal and Sri Lanka.

Load factor of the consumer

Because the payment for a load limited supply is fixed, the consumers bill does not change with the amount of electricity consumed. This discourages the household from being economical with their use of electricity and therefore high load factors can occur. With load limiters of several amperes there is the possibility in cold countries of a heater being left on throughout the night. With smaller load limiters heating loads are not possible but lights could be left on.

The limited data available indicates that in practice load factors may not be excessive. Load factors for the load limited consumers described in Section 3.1 are shown in Table 3 (Hancock et al 1988, Nafziger 1994). The load factor ranges between 24% and 37%.

Country	Load limit (Watts)	Load factor average (%)
Nepal	25	33
"	50	34
"	250	37
Zimbabwe	240	29
"	600	28
"	1200	29
"	1800	24

Table 3 Average load factors for load limiters in Nepal and Zimbabwe.

6.1.4 Cost

The price of MCBs varies little with current rating except for values below 1 Amp, as such sizes are rarely made. The cost of PTCs is approximately proportional to the current rating and is about $0.40 per 100 milliamps of current rating. The cost of ECCs is composed of a fixed cost for the control circuit and a variable element which increases with current rating.

At the Andhi Khola project in Nepal the load limits are classified in Watts. The 25 W or 50 W boxed PTC complete with a back up fuse costs approximately $3.5 (1994). The 100 W or 250 W boxed thermal MCB costs $8 and a 250 W ECC costs $12.5 (1994).

In general, PTCs are the cheapest form of load limiter for low current ratings (i.e. up to 500 mA). For higher current ratings MCBs are the cheapest. ECCs are more expensive but are more accurate than PTCs and thermal MCBs. They are still in the development stage and with large scale manufacture costs could be reduced substantially.

Load limiters are cheaper than meters. The cheapest standard meters from India and China cost approximately $15. Prepayment meters cost approximately $90. Volume production of complete, boxed load limiters would significantly reduce the unit cost.

6.1.5 Accuracy

The intrinsic accuracy of all three types of load limiter is within approximately 10% of the rated value if the temperature is constant. However, the overall accuracy of a load limiter is affected by the power factor of the load and by temperature changes.

Load limiters take no account of power factor because they measure current rather than power. Hence, appliances with poor power factors, such as tube lights, reduce the maximum power a householder can draw. It is possible to correct for poor power factor with capacitors. The main problem with connecting capacitors is one of implementation, as either the consumer must be taught what is required or legislation must be passed to ensure that poor power factor appliances are sold with power factor correction.

A variation in ambient temperature will effect the accuracy of a PTC and a thermal MCB. In some countries, the daily temperature can vary by 20°C, and annual variations of 40°C do occur. Both PTCs and thermal MCBs let through less current at high temperatures. Therefore, in order to ensure that they will not trip at their rated current on the hottest day, they will let through higher currents at cold times. The accuracy of magnetic MCBs does not suffer at all with variations in temperature. The accuracy of ECCs is only marginally affected by temperature variation.

It should be borne in mind that the inaccuracies described above are cumulative. With a PTC or thermal MCB, for example, the combination of inaccuracies due to manufacture, power factor and temperature effects can be over 50%. For a 100 W connection with a 30% load factor an inaccuracy of 50% would lead to 11 kWh per month of excess consumption. This is a relatively small excess consumption. However, for the same accuracy and load factor, the excess consumption is proportional to the load limiter rating. Hence, for higher value load limiters magnetic MCBs or possibly ECCs should be used.

6.1.6 Advantages

The main advantages of load limited supplies are:

(i) Low revenue collection costs

(ii) Reduced costs of transmission, distribution and generation

(iii) Low initial capital cost

(iv) Cash up front for the electricity utility

(v) Easier budgeting of payments by consumer

(i) Low revenue collection costs

Since payments are fixed, there is no need for meter reading or billing. Accounting is also simplified because payments do not vary. In order to ensure a net income to the utility, low billing costs are essential for supplies to households with low levels of electricity consumption.

(ii) Reduced costs of transmission, distribution and generation

Load limiters are an effective form of demand side management as they limit the peak demand. As explained in Section 6.1.3, their use can result in savings on transmission, distribution and generation.

(iii) Low initial capital cost

The savings to be gained by the utility through installing load limiters can be very significant. For example, in Zimbabwe the total cost of providing a service connection with a load limiter is $100 compared to about $150 for a metered supply. The workload is less and there are no delays associated with procurement, calibration, testing and installation of meters.

(iv) Cash up front for the electricity utility

Bills for load limited customers can be made payable in advance since the amount is fixed. This will improve the cash flow for the utility.

(v) Easier budgeting of payments by consumer

The fixed monthly payments for a load limited supply make budgeting easier for low income households.

6.1.7 Disadvantages

The main disadvantages of load limiters are:

(i) Increased opportunities for fraud and theft

(ii) Poor reliability

(iii) Restricted electricity usage

(iv) Poor accuracy

(v) Uneconomical use of electricity

(i) Increased opportunities for fraud and theft

The bypassing of load limiters can be a major problem for electricity utilities. This is difficult to detect because, unlike with a metered supply, there is no indication of the quantity of electricity consumed.

The present designs of load limiter all have the disadvantage that they must be accessible; the MCBs to be reset, and the PTCs and ECCs for fuse replacement. To prevent bypassing, the load limiter has to be placed in a sturdy box, made secure by a padlock and/or security seal. However, experience has shown that even these arrangements do not prevent tampering by the determined thief. A recent fraud in Zimbabwe was the replacement of 5 amp load limiters with 15 amp load limiters, with the consumer erasing the number 1 in the front! The utility detect this abuse by connecting a 3 kW load after each load limiter and checking that the load limiter operates. However, this is very time consuming.

With MCBs, theft can be reduced by using an additional MCB which is pole mounted and serves four or five homes. Thus, if anyone steals a large amount of electricity the supply to all the homes is cut off. In this way, social pressure deters theft. These pole mounted MCBs are less likely to be tampered with because they are less accessible and more public. A similar approach is being considered in the Ivory Coast (Pailly, 1993). If PTCs and ECCs can be improved so that they do not require fuses then they can also be pole mounted to reduce the likelihood of tampering.

Fraud by utility staff can also be a problem. For example, in Zimbabwe some of the utility staff have made arrangements with consumers for uprating load limiters such that the consumer pays the original tariff plus a secret payment to the staff member. These frauds are detected by regular checks at the consumer installation, using staff from other districts or depots.

(ii) Poor reliability

Poor reliability can be a problem. MCBs are inherently reliable devices when used properly. However, experience with 130,000 MCB load limiters in Zimbabwe, has shown that they can be damaged by the consumer. The damage is often done by the consumer repeatedly attempting to reset the device without first clearing the overload. The annual failure rate at Chitungwiza in Zimbabwe is approximately 9% for MCBs compared to less than 0.2% for electricity meters. At the Salleri Chialsa mini hydro project in Nepal, MCB load limiters are made inaccessible to the consumer (Widmer and Arter, 1992). An electrician has to reset the MCB after each overload, with the cost being met by the consumer. This is a disadvantage for the consumer but does protect the MCB from abuse.

A PTC can cope with repeated overloads of up to ten times its current rating and is therefore ideal as a load limiter under normal operating conditions. However, PTCs are not designed to withstand short circuits, and have to be protected by a carefully selected fuse. The fuse has to be made inaccessible to the consumer to prevent it being replaced by an unsuitable fuse or alternatives such as wire. If the fuse blows it has to be replaced by an electrician. If a PTC does fail it will become 'open circuit' and isolate the supply.

There are several thousand PTCs in use on micro-hydro projects in Nepal and Indonesia. Despite their apparent fragility, the PTCs have proven to be reliable and even able to withstand a few short circuits.

A PTC guaranteed to withstand short circuits would be a major step forward in load limiter technology since it would eliminate the need for a fuse and could be mounted on the distribution pole. Discussions with manufacturers indicate that it should be possible to develop such devices.

ECCs are still being developed and tested. They are similar to PTCs in that present designs need carefully selected fuses for short circuit protection. As with the PTC, design improvements are possible which may eliminate the need for a fuse.

(iii) Restricted electricity usage

Consumers generally prefer meters to load limiters because they can draw much more power. This became very apparent in Malawi where load limiters were tried in an area that previously had metered supplies. The response from customers was negative due to frequent tripping of the supply (Chisale, 1994). However, the high uptake of load limiters in Zimbabwe, as shown in Section 3.1, indicates that, where there is sufficient cost advantage, low income households will adopt load limited supplies.

(iv) Poor accuracy

As explained in Section 6.1.5, load limiters are less accurate than meters. The least accurate devices are those with thermal operation and these should be restricted to current ratings below one amp, as the excess consumption that results will be small. Higher currents should be limited using magnetic MCB or possibly ECCs.

Poor power consumption tolerances of domestic appliances can compound the effect of poor load limiter accuracy and result in some households being able to supply more appliances than others with the same value load limiter. Incorrectly labelled appliances can also cause problems and confusion. For example, in Nepal 'extra bright' 25 W light-bulbs can be purchased which are just incorrectly labelled 40 W bulbs!

(v) Uneconomical use of electricity

Load limiters do not encourage economical use of electricity because the consumers bill takes no account of the amount of power consumed. However, Table 3 shows that load factors on load limited supplies in Nepal and Zimbabwe are in the region of 30%, which is not excessive.

The limited life of electrical appliances discourages excessive use. In Nepal, there are cases of households leaving electric lights on all night. However, this practice is often stopped once the householder becomes aware of the cost in terms of replacement light-bulbs.

If load limiters of several amps are provided in cold climates electric heaters will be used and load factors are likely to be much higher than those given in Table 3. In such situations it may be necessary to restrict load limiter ratings to prevent the use of heaters.

6.1.8 The way forward

Load limiters are a very promising technology for reducing the cost of electricity supply to low income households, particularly in rural areas. There are some problems with the present types of load limiter, particularly regarding bypassing and reliability. These problems can be reduced by developing more robust load limiters that can be made inaccessible to the customer.

6.2 REDUCED SERVICE CONNECTION COSTS

Service connection costs can be broken down into the cost and installation of the meter or load limiter and the cost of the service cable and its support. Costs for service connections can vary considerably, as shown in Table 4.

Cost element	Cost in Sri Lanka (US$)	Cost in Botswana (US$)
Meter and installation	27.00	175.00
Cable per metre	0.16	7.50
Additional poles	50.00	80.00

Table 4 Service connection cost breakdown for Sri Lanka and Botswana (AFREPEN, 1992. CEB, 1994).

The figures are for the least cost connection available. In the case of Sri Lanka the consumer is restricted to just 5 Amps, though supplies with higher cut-outs are not much more expensive.

The service connection cost can be reduced by load limiters rather than meters, as they have a lower capital cost and reduce the size of cable required. Extra poles are required for service connections of more than about 30 metres. Alternative sources and types of poles can sometimes be found. For example, a study in Botswana discovered that decommissioned railway track could be used as poles and was less than one tenth of the cost of new wooden poles (AFREPEN, 1992).

Costs can also be reduced by providing several nearby households with service connections at the same time and through economies resulting from mass electrification programmes. On some electrification projects costs are further reduced by using looped service connections, i.e. feeding several customers from the same service cable. This is done on some of the township electrification projects in South Africa. The cable is fused at the pole, which also provides a disconnect facility.

6.3 PRE-FABRICATED WIRING SYSTEMS

House-wiring is a major expense that can deter households from subscribing to a connection, as explained in Section 5.2. The labour costs for conventional wiring are especially high for houses of traditional construction which make installation difficult.

A solution to this problem is the use of low cost versatile house-wiring systems. These come in two forms; wiring harnesses and 'Ready Boards'. Conventional wiring systems, as used in the west, are too expensive and inflexible for low income households in developing countries.

In developing countries extensions to house-wiring are frequent. When families get bigger or their income improves, they normally extend their homes rather than move. Hence, even if the initial wiring is installed to a high standard, the extensions are often wired by unqualified persons. Safe and versatile house-wiring systems are required to meet these conditions.

6.3.1 Wiring harnesses

Wiring harnesses are pre-fabricated house-wiring systems, produced in a range of standard sizes complete with in-line switches and light fittings. The wiring harness is connected to a junction box after the load limiter or meter or directly into the load limiter or meter. The wires radiate out 'octopus fashion'. Installation is a matter of fixing the cables to beams and exposed building supports. This is ideally done using large, plastic self-locking cable ties.

In the Andhi Khola Rural Electrification Project in Nepal, both conventional wiring and wiring harnesses are offered to the householders. The conventional wiring installations are approximately six times the cost of wiring harnesses. The most basic wiring harness, which is made for two lights or one light and one two pin socket costs just $4.30 (1994). Figure 6 shows a one light, one socket wiring harness installed at the Andhi Khola project.

The wiring harnesses are installed by trained villagers, under supervision by the electricity supply company, and the lights are placed in positions decided by the householder. The cables are always of ample length. The excess length is neatly strapped and tied and can be undone if the lights are moved. This reduces the problem of the householder extending the wiring by twisting bits of wire together.

Figure 6 Basic wiring harness, Andhi Khola, Nepal.

Figure 7 Load limiter used with the wiring harness of Figure 6.

The wiring harness was developed to provide a safe, low-cost means of wiring the traditional thatched roofed houses. However, it has also proved popular for the more solidly built houses with corrugated iron roofs.

> *" Not only did it reduce cost significantly, but it also provided for a bit more flexibility. It is not difficult to envision that, after some experience had been gained, homeowners might wish to shift the location of a bulb somewhat to shed more light in another portion of the room or to eliminate working in the shadow."* (Inversin, 1994).

The wiring harnesses are used in conjunction with load limiters and if the consumer pays for a higher current connection the wiring harness is upgraded to allow for extra loads to be connected. Figure 7 shows the load limiter box into which the wiring harness of Figure 6 is connected. A security seal is used at the top of the box to deter tampering.

6.3.2 Ready boards

An alternative or addition to a pre-fabricated wiring harness is a pre-manufactured distribution unit. This is aptly named a 'Ready Board' in South Africa where much of its development has taken place. The South African ready boards are connected directly after the meter, as shown in Figure 8. They provide consumer protection, facilities for connecting cable/conduit, and direct connections in the form of sockets. Some units also come with a top mounted light and in the lowest income households this is the only appliance used.

Even in the basic unit, the protection includes an earth leakage circuit breaker. Also included are overcurrent circuit breakers for one lighting and one plug circuit. The unit is very versatile as it has a number of breakouts for cables/conduits and the option of increasing the number of circuit breakers. A ready board is a part of the standard installation package used for township electrification projects in South Africa and there are a number of companies that manufacture them commercially (Atkinson-Hope and Stevens, 1994). The ready boards cost the utility approximately $40 (1994).

Figure 8 Prepayment meter and Ready Board, Ivory Park, South Africa.

A product similar to the South African ready board has been developed in Papua New Guinea. The electricity utility (ELCOM) call it a 'Minimum Service Supply Kit'. This is a similar concept to the ready board but, unlike the ready board, it contains a meter. Overcurrent protection is included but there is no earth leakage circuit breaker or breakouts for cable and conduit. There is just a single socket outlet.

The kit is a major step forward in terms of affordability when compared to conventional wiring, but it does have drawbacks. The single socket will encourage a lot of trailing cables for lighting and other appliances and in this case earth leakage protection really ought to be included along with provision for a wiring harness for lighting. The reason for this is that the wiring after the kit is the responsibility of the consumer and may be poorly done.

6.3.3 Conclusions

Wiring harnesses significantly reduce house-wiring costs and allow lights and sockets to be repositioned. They are ideal for consumers that use just one or two lights and perhaps a radio. Ready boards are significantly more expensive than wiring harnesses. This expense can be justified when a range of appliances and/or high current appliances are used, because of the extra protection that the ready board provides. The protection and safety aspects of wiring harnesses and ready boards are discussed further in Section 6.8.

6.4 CREDIT

The provision of credit for connection and house-wiring costs is a very positive incentive for encouraging low income households to obtain an electricity connection. Whilst households may have difficulty in raising the relatively large lump sum involved, they are often able to pay over a period of time and in part from savings on other fuels. However, credit has to be supplied carefully so as not to encourage households into debt that they cannot afford to repay.

Credit for electricity installation is available in quite a number of developing countries. The amount of credit available and the repayment period vary widely between countries. In Uganda the connection fee can be paid over a period of up to four months, whereas in Colombia credit is available over two to four years (Rwemereza, 1994. Gnecco, 1994). In most cases credit is only available for the connection fee. In a few cases, such as Sri Lanka and the Kutir Jyothi schemes in India, credit also covers house-wiring.

Where meters are installed, it is much better for the consumer to repay the loan by being charged more on the tariff rather than through an increased standing charge, because in this way households in temporary financial difficulty can reduce consumption in order to save money. This is particularly important in rural areas because seasonal factors result in appreciable variations in household income. This is highlighted by an example from Senegal:

> *"...........pattern of income and expenditure is completely at variance with the regular two-monthly billing of the electricity authority and would cause problems. A foretaste of this is provide by the experience of regular payments for water in some areas. In the immediate post-harvest period, payments come close to 100%, but they fall to 20% towards the end of the dry season. The present system of billing electricity consumers is well suited to salaried officials or urban dwellers with a regular job; but it is a major obstacle to the spread of electricity to the rural areas."* (ENDA, 1988).

However, electricity utilities generally prefer repayments of loans through an increase in standing charge because, provided there are no defaults on repayments, the loan is recovered in a fixed time. For example, ELCOM in Papua New Guinea provide interest free credit for their Minimum Service Supply, described in Section 6.3.2, and collect the payments through an increase in charges of approximately $6 per month for 24 months (1994). This charge alone is more than low income households can afford.

ESKOM in South Africa take a more flexible approach with regard to credit. They provide three payment options for consumers with expected consumption of less than 500 kWh per month. The individual has the option to select his unit tariff depending on the capital which he is prepared to pay at the time of connection. More than 95% of customers opt for the maximum credit option for which they pay just a $10 registration fee but a high unit charge (Engelbrecht, 1994). ESKOM provide the connection, meter and a ready board. As explained above, this approach is favoured by consumers and is likely to result in the highest connection rates. However, the utility must be sure that the extra income due to the higher unit charge will repay its costs. As shown in Section 3.2, the consumption level required for ESKOM to break even is 570 kWh per month. At present, the average electricity consumption is approximately 100 kWh per month and therefore the township electrification projects are far from being financially viable.

Credit may be best supplied by an external organisation or by local electricity contractors, as utilities often have their own cash flow problems and will be reluctant or unable to provide credit to consumers. In the successful rural electrification programme in Thailand, the Provincial Electricity Authority (PEA) initially provided credit of approximately $100 per household for the connection fee and house-wiring. However, only a few years after implementing the credit programme there was little need for it to continue as the local contractors were providing the credit themselves.

> *"Under pressure to secure a market, local electrician contractors created their own marketing strategies. Contractors themselves provided various types of credit and/or instalment schemes to customers for house-wiring and connection, eliminating the need for PEA to provide any credit incentive."* (World Bank, 1995).

This situation came about in Thailand because PEA had actively sought to use local contractors to perform the less technical tasks involved with grid construction. PEA had trained these contractors to a level such that they could do house-wiring and so, when the distribution system was completed, they were available and capable of carrying out domestic electrical installation work.

6.5 COMMUNITY INVOLVEMENT

6.5.1 Local community involvement

Community involvement is very worthwhile in the planning and installation of an electrification project and, in some cases, for tariff collection. The community can decide what it wants and how much it is prepared to contribute. The utility can benefit through reduced costs, greater coverage, and ease of implementation.

In Thailand financial contributions from villages were encouraged by providing a faster service to villages that made financial contributions. Villages that paid 30% of construction costs were electrified much sooner than normal and those paying full costs were immediately connected to the grid. This enabled PEA to reduce its connection charges which helped low income households to afford a connection. The clear prioritization system reduced political interference in the village selection process and therefore helped rural electrification to proceed efficiently (World Bank, 1995).

Communities can make a contribution 'in kind' to the cost of providing an electricity supply. This may result in significant cost savings. Even if there is no tangible contribution of materials or labour, a good relationship between the utility and the community can lead to a greater sense of responsibility. The benefits of this are reduced theft and vandalism. In addition, social pressure can prevent individuals from obstructing the utility and/or making large claims for compensation.

In Thailand the PEA recognised from the beginning that the local community could significantly contribute to their rural electrification programme. As a sign of their commitment the PEA construction crews were lodged in the village, either in rented rooms or in the local temple, which incidentally reduced PEA's costs. Skilled and unskilled labour was employed from the village or from nearby and paid market rates. Because the local people felt they were part of the program they often provided free labour and animals to transport construction equipment, and villagers allowed the use of their land for the distribution line and even cleared or cut back economic trees without financial compensation (World Bank, 1995).

In Peru the national utility encourages the formation of 'pro-electrification committees' in areas that are to be electrified (Foley, 1990). Through effective co-operation a high percentage of households can be connected as soon as the area is electrified. This reduces costs, due to the economies of connecting many houses at one time, and provides the utility with an immediate income.

The community can lobby for a supply and encourage electrification by committing themselves to taking a given number of connections. They can facilitate planning by advising on the routing of the distribution lines and by assisting with any right of way disputes. They can elect a committee which will aid communication between the utility and the community.

A good example of effective long term village involvement, on a small scale, is at the Andhi Khola Rural Electrification Project in Nepal (Nafziger, 1994). Local electricity user organisations (UOs) are promoted by community motivators. These are men and women employed from surrounding villages. The first UO was formed in the village of Aserdi. This was chosen because it had a history of community organised activity, enthusiasm and expressed willingness to contribute voluntary labour.

Initially, the UO consisted of 15 members under the chairmanship of a proven local leader. This large UO ensured a widespread involvement to generate the required voluntary labour for construction. After the construction was completed the UO was reduced to three members to make it easier for dealings with the electricity company.

The villagers provided distribution poles and labour for erecting them. They also assisted with transporting materials from the nearest road. Wiring harnesses were installed by two persons from the UO under supervision.

It is estimated that the UO contributed 11% of the total cost of the installation. In negotiations between the UO and the electricity utility it was agreed that, in return for the contribution of labour and materials, fees for electricity connection would be waived. More than 95% of households were connected.

As part of the long term involvement of the village, the UO is responsible for collection of fees, depositing the money and carrying out basic repairs and maintenance work. One member of the community is employed as the service person to undertake these duties. The monthly fees are fixed since every household has a load limiter rather than a meter. This is good for the electricity company, and the service person, since they both know the amounts of money which will be paid.

In return for the community's involvement the utility return 10% of the monthly payment which is used to pay the service man. This is considerably less than the cost to the electricity company of undertaking the revenue collection, let alone the maintenance work. In this case the maintenance work includes tree cutting around the distribution lines, regular inspection of house-wiring, fuse replacement and reporting of major faults to the electricity company.

To start with, individual payments were not forthcoming. So in September 1989 the electricity company shut off the supply to the whole village for a few days. Since then the collection of fees has generally proceeded more smoothly and it has not been necessary to cut off the supply again. The electricity company occasionally monitor the electricity consumption of the village as a whole in order to check for overconsumption due to illegal connections. The readings have always been acceptable and indicate no significant abuse of the electricity supply.

One disadvantage of community involvement is that because local people become familiar with domestic electricity installation they may be more likely to bypass load limiters and meters or make illegal connections. A sense of mystery and fear about electricity can have its advantages!

With metered consumers there are more problems with entrusting the community to provide a full revenue collection service. Households are more likely to default on payments as they may be faced with unexpectedly high bills that they cannot afford or refuse to pay because they consider that the revenue collector is overcharging them. The job of the revenue collector(s) is much more complicated as they must read the meters, keep accounts and deal with more problems of defaults on payments. It is easier for the revenue collectors to overcharge the consumers or underpay the electricity company as the payments are not fixed, and therefore the company must carefully monitor the work of the revenue collectors and the energy supplied to the community.

An alternative with metered consumers is for the job to be shared between the utility and the community, with the utility reading the meters and issuing the bills and the community collecting the payments. This is successfully done by the PEA in Thailand. A respected local person, such as a school teacher, village head or village elder collects the monthly bill payments. PEA compensates this person by paying them 5% of each bill with a maximum of $0.18 and a minimum of $0.08 per bill. PEA's costs have been reduced considerably and furthermore the non-technical losses, including delinquent/non-payments and illegal connections have also reduced. At present only about 10% of the villages in the country use this method of payment, though it is planned to introduce it to the whole of the country (World Bank, 1995).

Community involvement is more likely in rural areas than in urban areas because communities are more cohesive and cost savings have more impact because the economy is less cash based. However, in urban areas the use of local labour may also be a way of reducing installation costs.

Mobilising community resources must be part of a deliberate coherent policy from the beginning. This has been true of the rural electrification programme in Thailand and the Andhi Khola project in Nepal. If these approaches are to be successfully replicated elsewhere, they must be sensitively and carefully done as local community support cannot be taken for granted. Within rural communities there is often great inequality and exploitation. Organisations with rural development experience should be involved to ensure fairness. Establishing community involvement can be a long and time consuming process.

6.5.2 Cooperatives

It is important to differentiate between the local community involvement described above and the operation of electrification cooperatives. Electrification cooperatives, despite what their name implies, are generally large organisations similar to area distribution boards. For example, each electrification cooperative in Bangladesh covers a population of between 500,000 and 1,500,000 people (Foley, 1990). In most cases, each consumer becomes a member of the cooperative and takes part in the election of directors.

The success of cooperatives has been mixed. A major factor has been the extent of Government support or interference (Wasserman and Davenport, 1983). The World Bank has no clear preference between cooperatives and utilities.

> *"....the experience to date does not support one type of organisation over another in so far as some decentralised agencies as well as some cooperatives have carried out effective programs while others of both types have encountered problems."* (World Bank, 1990).

6.6 PREPAYMENT METERS

Prepayment meters require the consumer to purchase units of electricity from the supply authority in advance, in much the same way as filling up a car with petrol. With most existing systems, the consumer purchases a magnetic card which has the number of units recorded on it. The consumer inserts this into the meter which then records the new units as credits. The meter then automatically cancels the code on the card so that it cannot be re-used. The meter displays the number of credits and, depending upon the make, may also indicate the rate of consumption and/or provide warnings when the credits are almost exhausted. The advantages of the prepayment meter include:

- No meter reading required
- No billing required
- Prepayment means no overdue accounts and no disconnection and reconnection costs
- Easy budgeting by the consumer and the ability to pay for small amounts in the same way that kerosene is purchased
- No costs resulting from a change of tenant or home owner
- No consumer enquiries and complaints regarding bills
- Time of day tariffs can be programmed into the meter and easily modified

The main disadvantages of prepayment meters are:

- High cost
- A well organised sales / support service is required

Prepayment meters have been used extensively in South Africa during the past few years. They are used principally in the townships and are fitted along with ready boards, as shown in Figure 8. The meters cost the utility approximately $90 (Pretorius, 1994).

Initially there were a lot of teething problems. The fault level in the first year was in the region of 20%. Faults included lightning damage and environmental factors such as termite infestation (Prepayment electricity, 1994). Sometimes service engineers found that the fault was not with the meter but an inability on the part of the customer to operate it. This has been largely overcome by making the meters more 'user friendly' and by better instructions. Fault levels are now 3% a year and it is expected they will fall to below 0.5% in the long term.

Maintenance and administration costs are currently about $3.5 per meter per month (Pretorius, 1994). Maintenance costs are falling, as explained above. Administration costs are being reduced by using agents in local stores to operate the vending equipment, rather than having dedicated payment centres.

Prepayment meters make the consumer much more aware of their electricity consumption and in most cases lead to a reduction in consumption. For example, at Mhluzi in South Africa the average monthly electricity consumption with conventional meters fitted was 683 kWh. This fell to 230 kWh when prepayment meters were fitted and has evened out at 300 kWh (Prepayment electricity, 1994a). Low income households often make the greatest savings:

> *"Most prepayment electricity user groups show some reduction in energy usage, which has been found to be related to affluence, where lower income groups show the greatest savings."* (Youngleson, 1994).

Whether this feature of prepayment meters is of benefit to the electricity utility will depend upon the availability of spare capacity in the generating, transmission and distribution system. Where these are heavily loaded, pre-payment meters could be a lower cost option than upgrading the supply.

Prepayment meters are well suited to urban consumers with monthly electricity consumption of 100 kWh or more. High initial costs and relatively high operating costs make them less suitable for households with low consumption levels. This is especially the case in rural areas as administration costs will be higher due to lower population density.

Prepayment metering technology is developing quite rapidly. Remote metering systems are being developed that enable meter reading, crediting of prepayments and disconnection/reconnection to be carried out by communications over the distribution network. These systems could be cheaper than the more conventional prepayment systems, both in terms of hardware and running costs.

6.7 TARIFF REFORMS

Tariffs should be set to give the utility sufficient income to be financially viable without discouraging consumers from either obtaining a supply or using electricity. The World Bank recommend a tariff level of 8.5 cents per kilowatt hour in order to cover operating costs, make equity contributions to investment needs and attract loan financing on commercial terms (World Bank / IFC, 1994). Tariffs are often set too low and result in the utilities running up large debts and being unable to maintain, let alone expand, the supply system.

Tariffs often consist of a fixed charge, or standing charge, and an energy charge. The fixed charge generally covers the cost of revenue collection. This can be reduced by using load limiters and community involvement, as described in previous sections. Low income households cannot afford to pay high fixed charges, as they only have a small amount of money to pay their complete electricity bill.

High energy costs are less of a deterrent than a high fixed charge. They are likely to restrict the amount of electricity consumed but unlikely to deter low income households from obtaining a supply. As explained in Section 2.2, the high cost of kerosene and batteries mean that consumers are prepared to pay high electricity charges for lighting and radios.

> *"....many utilities could charge a great deal more for their rural electricity supplies than they do without compromising the benefits and development effects of programmes. Prices of 20 cents per kWh for households, farmers and small businesses would leave most of the beneficial effects of rural electrification intact in probably the majority of cases."* (Foley, 1990).

Some utilities provide a low tariff, often known as the 'lifeline tariff', for low income households. This will encourages low income households to obtain a connection and helps them to pay for the electricity. However, the lifeline tariff should be restricted to very low consumption levels to prevent the utility from being overburdened. In Bangladesh the lifeline tariff applies to the first 70 kWh of monthly electricity consumption, whereas the average domestic electricity consumption is approximately 24 kWh (De Lucia and associates, 1989). A lifeline tariff for just the first 10 kWh of monthly consumption is sufficient to supply two 40 W light-bulbs and a radio for 4 hours per day. By using load limiters, lifeline rates can be restricted to just the low income households.

As explained in Section 5.3, confusing and frequently changing tariffs can deter low income households from obtaining or using electricity. For this reason tariffs should be kept simple. The charges should be revised at set times and the new rates should be widely advertised.

6.8 REVISED SAFETY STANDARDS

In many countries, households with traditional thatched roof houses are not allowed an electricity supply because they do not have a permanent watertight roof. In Tanzania, for example, the average cost of upgrading a house to the standard required by the utility, as well as paying for the connection and putting down the security deposit is estimated to be around $250. This compares with $4 in Bangladesh, where there is no connection charge for consumers within 30 metres of the distribution line and houses of traditional construction are supplied (Foley, 1990).

Figure 9 Service connection to thatched roofed house, Andhi Khola, Nepal.

> *"The cost of meeting the standards for building construction and house-wiring statutorily demanded by utilities.............(is) a major deterrent to many people, especially those with low incomes. In some cases, these standards were imposed during colonial times and deliberately excluded traditional and low cost dwellings. Experience throughout the developing world has now shown that electricity supplies can be provided to such dwellings without compromising safety standards."* (SEI/BUN, 1993).

Thatched roofs for domestic dwellings are generally kept watertight. However, for extra safety, cable and fittings for exterior use can be specified. The dangers associated with running the service connection under the thatch can be prevented by specifying that either armoured cable or conduit is used up to the meter or load limiter.

The wiring regulations used in developing countries are generally the same as or similar to western regulations. For example, both Central African and Indian wiring regulations are very similar to IEE wiring regulations. The regulations are usually enforced by an engineer from the utility inspecting the house-wiring before the electricity supply is connected.

The author's experience, from short field visits in India and Zimbabwe, was that the initial house-wiring, completed before the supply was connected, was carried out to a high standard. However, extensions to the house-wiring were often crude and dangerous. As mentioned in Section 6.3, extensions to house-wiring are frequent, as when families get bigger or their income improves they normally extend their home rather than move.

Figure 10 Crude extension to house-wiring, Zimbabwe.

Extensions to house-wiring are often carried out by unqualified persons in an attempt to save money. Figure 10 shows the start of a crude wiring extension taken from the back of a socket outlet in Zimbabwe. In both India and Zimbabwe cable connections were found where wires had been twisted together and the bare ends left exposed. In one case the exposed connections were on the ground in an area where children were playing.

With the Kutir Jyothi supplies in India, in theory, dangerous wiring should not be a problem as the households are only allowed to use a single 40 W light-bulb, for which the light fitting is installed when the service connection is provided. However, in all the houses visited, crude and highly dangerous alterations had been made to the wiring in order to add on extra appliances. In several cases the supply fuses, the only current limiting devices, had been bypassed with wire making the installations highly dangerous. It was no surprise to find that in all cases 60 W or 100 W light bulbs were being used in the light fitting provided.

Wiring harnesses, as described in Section 6.3.1, can reduce the problem of dangerous wiring extensions as they allow the household to reposition electrical fittings and extra fittings can be added relatively easily. The dangerous wiring extensions found in India and Zimbabwe were not seen during a visit to houses at the Andhi Khola project where wiring harnesses are in use. Wiring harnesses are not as safe as properly installed fixed wiring but are usually safer than the wiring found in the houses of poor people in developing countries.

Wiring harnesses, when used alone, are appropriate for households who only need one or two light-bulbs and perhaps a radio. They are appropriate because they are cheap and versatile and, because light fittings and radios are generally double insulated, they are acceptable from a safety point of view. For this type of low load application a load limiter is ideal because, in addition to load limiting, it provides overcurrent protection. Current values are relatively low (generally less than one amp) and it is easy to size all the wiring for the maximum current.

When more appliances are used, particularly those that must be earthed, the risk of electric shock increases and compulsory earth leakage protection should be considered. For high current appliances, a metered supply is likely and overcurrent protection is required because the meter itself does not protect the house-wiring.

Since ready boards contain both overcurrent and earth leakage protection they are ideal for applications where many appliances and/or high current appliances are used. Dangerous wiring was seen by the author on a visit to a township electrification project in South Africa, though there was greater protection as all homes were fitted with a ready board containing an earth leakage circuit breaker.

Electrical safety will be further improved by greater education on the dangers of electricity and more inspections of house-wiring.

When weighing up the safety requirements for electricity installation it is important to be aware of the safety implications of using kerosene and candles. This is highlighted by research in South Africa:

> *"Electrification permits the removal of potentially dangerous energy sources such as biomass fuels, coal and paraffin from the domestic environment and its positive benefits are thus mainly through the reduction in burns, housefires and paraffin poisoning. South Africa has a burn fatality rate which is four times higher than that of the industrialised world. The main reasons for this lie in the high levels of childhood burns and scalds in the home and the catastrophic nature of housefires in areas of informal settlement......One of the major causes of housefires is the use of candles for lighting and it would therefore be expected that electrification, even if only used to limited extent for domestic lighting, would reduce burn injury and deaths.......With special reference to shocks and electrocutions, limited available national statistics, indicate that this is not a major public health problem."* (Lerer, 1994).

One reason why shocks and electrocutions are not a major public health problem in South Africa is that it is one of the few countries in the world to require mandatory installation of earth leakage protection for all socket outlets (Cohen and Tsiaparis, 1992). Data should be gathered from other developing countries to examine the main causes of electric shock and electrocution and the effects of electrification on health and domestic injury and death rates. Safety experts in electricity utilities and health and safety bodies should be consulted and options such as wiring harnesses and earth leakage circuit breakers discussed. This information should be used to revise safety and electrical installation standards.

7 ACCEPTABILITY OF SOLUTIONS

Feedback and suggestions regarding the solutions discussed in this report was obtained from 15 developing countries, as a result of questionnaires, correspondence and visits. The responses were generally very positive. Electricity utilities in a number of countries are interested in undertaking pilot projects using some of the new approaches discussed in Chapter 6. The expressions of interest came from Laos, Malawi, Nepal, Sri Lanka, Tanzania, Uganda, Zambia, Zimbabwe and the Andhra Pradesh and Karnataka states in India.

The technical solution that is felt to be most acceptable is the use of wiring harnesses and ready boards to reduce house-wiring costs.

There is also considerable interest in using load limiters rather than meters, though there are some reservations. In Malawi and Uganda load limiters have been tried and discontinued, largely because of customer preference for a metered supply. In South Africa, ESKOM are keen to try load limiters, especially in rural areas, but are holding back because the limited supply that they provide may be considered politically unacceptable. In Zimbabwe, where the electricity board have persevered with load limiters, the technology is accepted by the consumers and has been in use since the 1960s. Low income households benefit by being able to afford a basic supply that can be upgraded to a metered supply. The electricity board benefits by reducing its connection costs and revenue collection costs.

The response on pre-payment meters is mixed. Some utilities are very interested whilst others consider them to be too expensive, particularly for supplies to low income households.

Credit is seen as a good solution to increasing the number of low income households connected. However, there is concern that electricity boards often do not have the necessary funds and can have problems with defaults on payments.

Utilities are interested in increasing community involvement as they can see advantages in terms of savings on investment and possibly maintenance and collection costs. However, there is concern about the practicalities of organising and implementing such schemes successfully.

8 GUIDELINES FOR UTILITIES

These guidelines are designed to assist utilities in dealing with connecting low income households to the electricity supply.

1) The electricity usage, peak demand and payments of low income households, both in rural and urban areas, should be determined from records and monitoring in order to determine typical consumption and payment levels.

2) Technical options such as pre-fabricated wiring systems, load limiters, and prepayment meters should be assessed in terms of cost savings to the utility and consumers, acceptability, ease of implementation and maintenance requirements, bearing in mind the typical consumption and expenditure of low income households. The assessment should take account of previous direct experience with the technologies and experience in neighbouring countries and internationally. The best option(s) should be implemented, initially on a trial basis.

3) A credit program for both connection fees and house-wiring should be developed with advice and involvement from banks and other agencies that provide credit. The repayments must be affordable by low income households.

4) All possibilities for community involvement, including financial and labour contributions, electrification committees, and assistance with maintenance and revenue collection should be assessed. Advice should be sought from similar initiatives such as community farming and forestry projects and from neighbouring countries where the utilities make use of community involvement. Those options which are practical and beneficial to both the community and consumers should be implemented, initially on a trial basis.

5) Tariffs should be set so that they do not deter low income households from obtaining a connection. With metered supplies, fixed charges should be kept low, whilst energy charges can be set so as to recover costs.

6) Electrical safety in low income households should be assessed by examining available data and consulting experts on deaths and injuries caused by domestic electricity. New studies should be carried out if national data is unavailable or insufficient. Data and experts from neighbouring countries with different safety policies, such as those that allow connection of thatched roofed houses, should be consulted. This information should be used to revise safety standards, education programmes and the actions taken to ensure that safety standards are observed.

9 COST SAVINGS

The cost of electricity installation for low income households can be reduced by implementing a number of the solutions discussed in Chapter 6. The most significant cost savings arise from:

- Load limited supply
- Pre-fabricated wiring systems
- Community involvement

The magnitude of the cost savings will vary between and sometimes within countries and therefore it is not possible to give accurate figures. However, it is possible to provide good indications of the savings that can be achieved.

9.1 LOAD LIMITED SUPPLY

Load limiters can provide considerable cost savings. There are three main areas of cost savings; maximum demand related costs, meter costs and revenue collection costs.

Maximum demand related costs

The greatest cost savings resulting from the use of load limiters arise from a reduction in per customer maximum demand. The load limiter limits the maximum demand and thus reduces the capacity of the generating, transmission and distribution equipment required to serve the customer, as explained in Section 3.2.

The magnitude of the savings will depend upon the amount by which the maximum demand is reduced. At typical equipment prices, the saving in dollars will be approximately equal to the reduction in after diversity maximum demand in watts.

Meter costs

Load limiters are cheaper than meters. The cheapest meters are produced in China and India and cost approximately $15. As discussed in Section 6.1.4, load limiters presently cost between $3.5 and $12.5, depending upon current rating and type. The cost of load limiters will fall if they are produced in greater quantities.

Revenue collection costs

With load limiters there is no meter reading or billing required and administration is simpler. Savings of one or two dollars per customer, per year are typical. The savings will be higher in areas of low customer density and/or high wages.

9.2 PRE-FABRICATED WIRING SYSTEMS

Pre-fabricated wiring systems can reduce house-wiring costs substantially. A simple wiring harness for two light fittings can be produced and installed for less than $5. If conventional wiring were installed the cost would usually be more than $30. Where more light fittings and socket outlets are required a pre-fabricated system using a ready board and wiring harness will cost approximately $50, which can be less than half the price charged for conventional wiring.

9.3 COMMUNITY INVOLVEMENT

Community involvement can result in cost savings in several areas:

- Reduced labour costs for distribution, service connections and house-wiring
- Reduced revenue collection costs
- Reduced maintenance costs

Labour costs can be reduced by 10% or more by employing local people for the less skilled tasks. If the community undertakes the revenue collection and basic maintenance then these costs can be more than halved, especially for remote communities. For example, at the Andhi Khola project in Nepal, the service man collects the revenue and carries out basic maintenance at a cost of approximately $0.05 per consumer per month (Inversin, 1994).

10 FURTHER WORK

10.1 IMPROVED CHANNELS OF COMMUNICATION

As shown in this report, electricity utilities in a number of developing countries have developed innovative solutions to the problem of providing electricity to low income households. The approaches that they use could be replicated in other countries and be beneficial both to low income households and the utilities.

Unfortunately this work is rarely publicised. It is often unpublished or mentioned only briefly in long internal reports. As a result, there is little awareness of what neighbouring utilities are doing to address the problem of connecting low income households, let alone utilities on other continents.

This lack of communication can be addressed by establishing a network for engineers working in this area. Information exchange can occur and be encouraged through a regular international newsletter for the dissemination of information on low cost electricity supply techniques and experiences. The newsletter would contain short, practical informative articles written by members of the network and with emphasis on a different aspect of low cost electrification in each edition.

A similar network and newsletter called 'Hydronet' was established for micro-hydro engineers in 1988. These engineers faced similar problems in terms of isolation and lack of access to relevant information. Hydronet has helped many of these engineers to develop better systems through learning from the experience of others. The basis for a network for those involved in providing electricity to low income households is in place as a result of the contacts made during this study.

The newsletter would be very important for establishing and building up contacts between engineers concerned with low cost domestic installation. It would require initial funding, of approximately £50,000 per year, for two to three years in order to become established. It could then be self-sustaining through advertising revenue and subscriptions or as a supplement to a commercial electrical engineering magazine.

10.2 TECHNICAL DEVELOPMENTS

Technical development work is required to further improve PTC and ECC type load limiters. These have the advantage over MCB load limiters that they do not need to be manually reset. If these types of load limiter can be redesigned so that they are short-circuit proof and therefore do not require fuse protection it will be possible to mount them on distribution poles, thus reducing the likelihood of bypassing.

Controlled short-circuit tests should be carried out on existing types of PTC as it has been observed that these are more robust than old designs. These tests should be carried out over a range of temperatures and a supply resistance that is much less than the cold value of PTC resistance. If these devices are damaged by application of such direct short-circuits then the development of new more robust devices should be investigated. If new devices are developed then attention should be paid to improving their accuracy, especially with respect to variations in ambient temperature.

The ECC should be further developed. As with the PTC, particular attention should be paid to making the device short-circuit proof. An inbuilt current dependant delay is required so that current transients due to motor starts or capacitor charging, such as the high initial current into television sets, do not cause the ECC to trip. The switching device, be it a triac or thyristor, must be robust enough to withstand such current transients and the delay time must be short enough in the event of a short-circuit to prevent the switching device from being damaged. Attention should also be paid to cost minimisation and design for mass production.

Manufacturing companies should be involved in the development of these products, in order to ensure that they are designed for volume production and available for purchase as soon as possible.

10.3 DEMONSTRATION PROJECTS

Carefully monitored field trials are required for the further development of the PTC and ECC. The MCB type load limiter, wiring harnesses, ready boards and prepayment meters, described in Chapter 6, are well proven and should be demonstrated in different countries. By undertaking pilot projects in different countries the wider uptake of these cost-saving technologies will be facilitated. Care must be taken to ensure that the technologies are suitable for management and implementation by the utility and meet the needs of the customers. For example, prepayment meters should not be installed unless staff have been trained, the billing and dispensing facilities are organised and close enough to the households, and the householders can understand how to operate the meters and will consume sufficient electricity to make their installation worthwhile.

In addition to establishing demonstration projects for technical developments, demonstration projects using new credit approaches and increased community involvement should be established. As recommended in section 6.5.1, organisations with extensive community development experience should work alongside the utility to assist with establishing and sustaining community involvement. All the demonstration projects should be carefully monitored and compared with standard electrification projects in terms of the socio-economic impact and the advantages and disadvantages of any new technologies used.

The costs of setting up and managing the projects, providing technical advice and training, and technical and socio-economic evaluation will be in the region of £45,000 per demonstration project. This excludes costs of connection and house-wiring, which will vary according to the technology being demonstrated and the number of houses connected.

APPENDIX 1: TERMS OF REFERENCE

Intermediate Technology Consultants Limited would assemble a small team of experts to complete an initial study and overview report. The objectives would be to:

- Provide in a single reference document a review of the problems faced by poorer users and potential users and the constraints faced by power utilities.
- Identify possible technical solutions existing or under development.
- Identify how such solutions might be implemented through modified policy standards, training/technology transfer and hardware development.
- Identify possible areas for monitoring performance of existing systems or field trials of new developments.

APPENDIX 2: ORGANISATIONS VISITED

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