ENERGY FOR RURAL COMMUNITIES

Introduction

Rural areas in developing countries have limited access to all types of services, including health, clean water supplies, communication and roads. This lack of access is also true for energy services. Nearly a third of the world's population do not have access to grid electricity and the majority of these people live in rural areas of developing countries.

Most of these people have no hope of being connected to a mains electricity grid in the foreseeable future, despite the political pressure of governments to increase grid connectivity. Given the choice, and the money, most people would opt to switch to electricity.

Figure 1: Domestic lighting. Micro-hydro project which supplies electricity to the community at Galyang Nepal. Photo credit: Practical Action / Caroline Penn.

Household electricity consumption

Electricity consumption shows large variations depending on climate, culture, reliability of supply, and location. Generally, rural households in developing countries have very low consumption, with the primary uses being lighting, radio and television.

The load factor is a measure of actual energy used compared to the maximum possible energy available for use. For small-scale energy delivery it is important to know the load factor and the peak energy demand in order to extract the best possible use form the energy system. In most cases the load factor within the rural setting is below 0.2 but peak demand can often exceed capacity.

Where lighting is the only significant use of electricity, monthly consumption tends to be in the range of 10 to 20 kWh. Two 40-watt incandescent bulbs used for five hours each night, for example, have a monthly consumption of 12 kWh. A radio-cassette player and a small fan can be used for 10 hours each day for an additional consumption of 10 to 15 kWh per month. A small colour TV used for 6 hours a day will add a further 10 kWh a month. A family could accommodate all these uses easily within a consumption range of 50 to 60 kWh a month. A refrigerator uses about 50 kWh and a freezer around 100 kWh a month. Ideally, extra demand would occur during off-peak periods in the middle of the day. Efforts have been made to increase the use of electricity in commercial activities that will use energy during this time, while limiting demand at peak periods.

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technical brief

Energy options

Renewable energy options are increasingly well developed technically and markets are expanding but severe constraints on the market remain. Governments of many developing countries are working to increase grid connectivity although progress is slow and the growth often does not keep up with demand. The more densely populated areas tend to receive priority over others with lower populations, since more people can be connected to the grid supply for the same cost.

When attempting to bring renewable energy technologies within range of poor people it is important to work with the existing market to ensure that it is locally sustainable – not only economically and environmentally but in a range of factors that contribute to technological sustainability:

- Local manufacture and product support
- Local ownership and management
- Community and individual financing, especially from micro-finance

Figure 2: Nilde Portal charging the batteries. Her family owns an improved mill at Cuichupucro to which local villagers bring their grain. Photo credit: Practical Action / Steve Fisher.

Involving rural people

Although there will be differences in the way projects are implemented, it has been found that successful projects involve the people affected in the planning and decision-making, often through the community committee. Many benefits are particular to women such as the provision of mechanised grain milling services, replacing labour intensive traditional methods of grain milling and it is important to include women representatives in the committee.

Involvement of users results in a more efficient, rational use of resources and more equitable sharing of the benefits of development and by involving users from the beginning the costs can be reduced by using local labour to build the infrastructure and, with training, carry out installations and maintenance thus ensuring a better and cheaper service for consumers.

Rural development is dependent upon making energy services more readily available to people living in remote areas. Ideally, energy services should be introduced within the framework of wider infrastructure and economic development.

Combining development activities in such a way will strengthen the chances of successful community based energy provision and enable the communities to improve their livelihoods and generate additional income.

Delivering electricity

Mini grid system arrangements can include a distribution network with AC power stepped up to higher voltages for distribution, from 0.4kV for lower voltage distribution and from 11kV for higher voltage transmission lines. The electrification of villages with scattered houses and settlements using AC power systems requires a costly distribution network.

Hybrid systems combine renewable energy systems such as wind and solar with a diesel generator for a more consistent supply. There is a growing interest in integrated systems of energy delivery yet there is still only limited adoption of energy systems for the rural poor, primarily because hybrid energy systems add to the cost of energy delivery.

Stand-alone systems usually incorporate battery storage and have a 12v DC circuit. The advantages of village electrification schemes using batteries include:

- The low-voltage battery excludes the danger of electric shocks within houses
- The battery technology is a relatively simple and well known, being applied in vehicles throughout the world.
- Low load factor usage

The disadvantages include:

- The cost of electricity from rechargeable batteries can be very high
- Battery life can be short if not properly used and maintained
- They have a limited energy output which confines their use to lighting, radio and other small appliances, which are not directly productive end uses

Another common practice for obtaining electricity is through pre-electrification battery charging services. Remote energy systems cannot always supply power to all the households wishing to receive it because of limited capacity or houses can't afford the tariffs or the connection charge.

This has resulted in the establishment of battery charging enterprises in which people can take batteries, usually lead-acid car batteries, to a centrally located energy supply such as a micro-hydro scheme.

Battery charging can be done during the periods when the power system is not being used to its full capacity thus improving systems load factor.

Technologies for affordable electricity
One aspect to making energy schemes successful is to reduce the cost of the scheme through the various methods outlined below.

- Sizing the system components to suit demand
- Local manufacture
- Selection of appropriate technology for components

Small-scale manufacturing plays a huge role in the development of any region. Renewable energy technology can be used to stimulate indigenous manufacturing. The technology has to be appropriate for the region in question, or adapted to make it suitable. By developing small-scale manufacturing, renewable energy can be introduced to more users at a lower cost than sophisticated imports, and equipment can be repaired and maintained more easily. Local manufacture creates employment and local added-value, improving the general economic situation.

Once a system is installed it has to be adequately maintained, so a support infrastructure needs to be established. This may require a training programme and appropriate documentation, regular refresher training, and an accessible supply of spare parts.

Transmission and distribution lines

Mini distribution systems require careful consideration as they can potentially add a huge amount of expense to a scheme.

Standard distribution systems based the principles of national grid systems are over engineered for rural electrification schemes. Consequently, various low cost alternatives have been used for such schemes.

- Three-phase high voltage
  Three or four wire systems can be used for three-phase high voltage systems. Four wire systems use three phase wires and a neutral return. With the three-wire approach limits the voltage that can be supplied voltage between phases known as the phase

voltage, which is acceptable for high voltage (HV) distribution systems but not suitable for low-voltage systems. The main advantage is in the cost benefits associated with the reduction of the number of wire required.

- Three-phase low voltage lines
  Three-phase wiring is relatively expensive for low voltage distribution that can use single-phase options.
- Single-phase low voltage lines with wire return
  There is a cost benefit in reducing the number of wire associated with single-phase systems compared to three-phase. The disadvantage of single-phase systems is that the power delivery is not as smooth as a three-phase system, which can affect the performance of electrical devices.
- Single wire earth return (SWER)
  A single-phase supply using the earth as the return reduces the costs even further by eliminating the return wire. The system was developed in New Zealand in the 1920s for rural energy supply.

In practice, a combination of transmission lines may be used depending on the size of the distribution grid in question. From the power house there could be a three-phase high-tension power line to minimise power losses, which can then be stepped to a lower voltage single-phase lines for local distribution. In most mini-grid systems the distance of the supply lines will only be a few kilometres. By comparison, national grid extensions to rural areas requires much longer lines resulting in the need to upgrade the system to avoid excessive transmission losses.

Distribution lines need to be supported off the ground at a height that means they will not interfere with people's activities or transport, and will not be dangerous. The poles have certain requirements in terms of their size and strength, to counter wind conditions. In mini-grid systems the distribution poles can be a significant cost of the overall project.

In the home

Special approaches are required for low-cost electrification in the home if connections are to be economic. In subsistence farming communities, the average household expenditure on electricity can be less than $1 per month.

The electricity consumption of low-income households is often just a few tens of kilowatt hours (kWh) 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.

With appropriate techniques, houses can be connected safely and with fewer dangers than those associated with the use of kerosene and candles. The dangers from electricity supply can be kept to a minimum by using earth-leakage circuit-breakers, flexible wiring systems, education, and regular safety checks. The high costs faced by new consumers can be reduced through the careful application of appropriate technologies such as prefabricated house-wiring systems, e.g. wiring harnesses and ready boards.

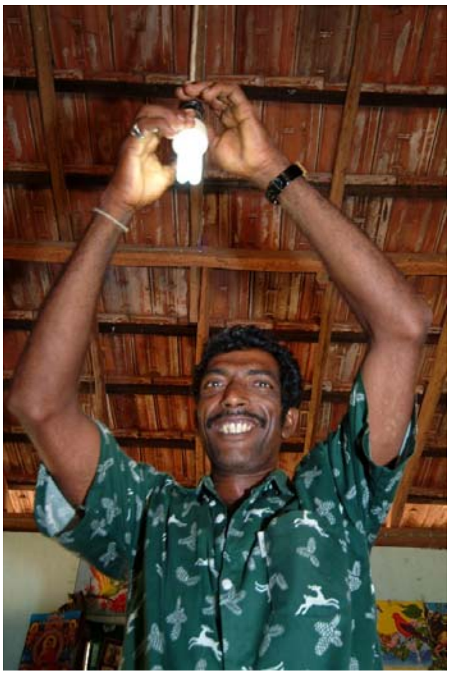

Figure 3: Mr. Vimalasene installing a low energy bulb in his house in Sri Lanka. Photo credit Practical Action / Zul

Load limited supply

Load limiters have been successful in reducing the connection cost and the operating cost of electricity supply. The basic principle is to limit the current to a pre-prescribed maximum. If the current exceeds the stated maximum then the limiter will disconnect the supply. The cost savings associated with load limiters are significant as they allow the reduction in scale of generation and transmission of electricity and in the time and cost of installation. Billing and revenue-collection costs can be reduced.

There are a number of options of load limiting devices:

- Miniature Circuit Breaker (MCB)
  This is the most common type of circuit breaker used and consequently the most familiar to electrical engineers. MCBs are mass produced, robust and inexpensive.
- Positive Temperature co-efficient thermistors (PTCs)
  These devices are made from solid-state semiconductors. Again, the items are mass-produced and are used in consumer goods and telecommunication equipment. They are less common in household connections as they have a low current rating of typically 20mA to 500mA, which means they are not suitable for conventional electricity connections but can be used in restricted power supplies.
- Electronic Current Cut-Out (ECC)
  The Electronic Current Cut-Out (ECC) is a more recent option for limiting load. They were specifically developed in Nepal for this purpose. The ECC is not dependent on a change temperature but measures the voltage. This voltage is an accurate measure of the load current and is used to turn off the electronic switch when the current is too high.

Prefabricated distribution units
These are prefabricated distribution units known in South Africa as Ready Boards and in Papua New Guinea as Minimum Service Supply Kits. They are a standard unit that is connected after the meter or load limiter and enable consumers to connect up their household with safety. In some cases they have a light fitting directly on top of them and in the cheapest form this may be the only load. Others have a number of breakouts for cables that can be used for additional loads. They incorporate consumer protection facilities including an earth-leaking circuit breaker, as well as overcurrent circuit breakers.

Wiring harnesses
As with the ready boards, wiring harnesses are prefabricated units but they include the wiring as well as the distribution unit. They are complete house wiring systems that are quicker, easier and cheaper to install than the conventional approach to wiring houses. The harness is made to a standard format and available in a range of sizes so houses can determine the service level they require. Switches and light sockets are already built in at the time of assembly, and the wiring radiate out from the central control box that can include a load limiting device and fuses.

The design was originally developed as a safe option for traditional thatched houses but has been widely applied to other forms of housing. Generally the wiring is not built into the walls of the house but is fixed to the wall surface. The cables can be quickly attached to the walls using self-locking cable ties. Any excessive length of wire is folded away rather than cut down so that fittings can be moved at a later date if required. This is particularly useful when extensions are added to a building. If local villages receive appropriate training, supported by the electricity supplier, then they are able to install wire harnesses.

Batteries
For renewable energy systems, it should ideally be possible to use most of the energy stored in a battery so that the time required between recharging is as long as possible but lead-acid vehicle batteries are the most readily available and most commonly used type of battery in renewable energy systems in developing countries. These batteries are designed to give a short burst of current to start the vehicle and then to be recharged immediately so the depth of discharge is never very great. Consequently, the discharge should be kept within 30% of the rated capacity and should not be left discharged for any length of time, in order to keep the battery in good condition and maintain its capacity and performance. Batteries may begin to

fail after less than 100 cycles of discharging to 50% of their capacity.
Where available, deep cycle or traction batteries are a better option as they can be discharged up to 80% of their rated capacity with life cycles from 1000 to 2000. Batteries specifically designed for solar systems have been developed. They are delivered dry-charged and the electrolyte is added once they have been installed. The life cycle range is typically around 1200 at 80% discharge to 3000 at 50% discharge. Sealed maintenance free batteries have a good life cycle of 800 cycles at 80% discharge but they need to be regularly recharged to prevent sulphate build-up and are expensive. These batteries are more expensive and less widely available but are more economical over their lifetime.

Lighting options

As lighting is usually the first use of domestic electricity systems in remote settings it is important to keep the consumption of lighting units down. Over recent years there has been a huge improvement in the efficiency of lighting units compared to traditional incandescent bulbs.

Low-wattage cookers

Cooking with electricity offers benefits to health and the environment, as it can replace fires that fill houses with smoke and cause many respiratory illnesses, and reduce the dependency on scarce resources of wood.

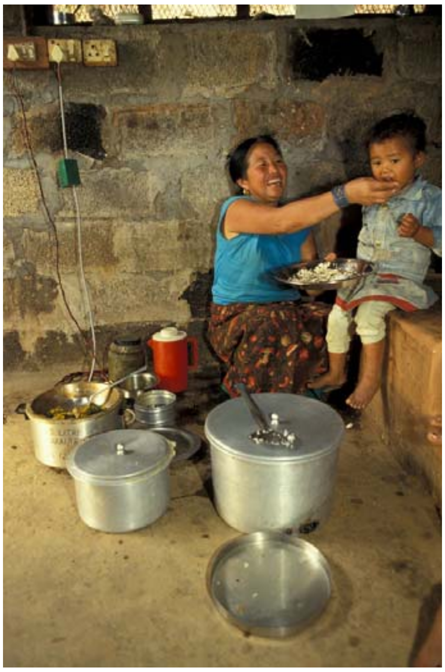

Figure 4: Low-wattage electrical cookers provide a clean environment and improve the load factor of micro-hydro schemes in Nepal. Photo credit Practical Action / Caroline Penn

Conventional electric cookers have a very high energy consumption, but low energy electric cooking devices have been developed in Nepal by Development Consulting Services and are now manufactured commercially. Normal electric cookers consume about 1Kw per plate, which is far too high for the majority of renewable energy schemes. A simple meal for four people would needs about 1 kilowatt-hour of energy to cook it, and generally people in a community tend to cook at about the same time.

In recent years health and environmental issues have become more prominent. Clean domestic energy reduces smoke exposure and lessens the need for fuelwood thus reducing deforestation, land degradation and the consequent impact on climate change.

Successful implementation of renewable energy schemes in rural areas is dependent upon a complex mixture of technological innovation combined with economical and institutional developments.

References and further reading

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Energy for Rural Communities was originally written for the *Appropriate Technology* magazine Volume 24/Number 2 September 2005 by Neil Noble.

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