Small wind energy systems for battery charging

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1. INTRODUCTION

This paper concerns the UK Department for International Development-funded project 'Small Wind Systems for Battery Charging', which is concerned with providing electricity to remote and isolated villages in Peru and Sri Lanka. At the time of writing, the project is half way through its four year duration

At present many households use car, lorry or motorcycle batteries to provide electricity for lighting, radios and TV. The use of a suitably sized wind generator to charge these batteries could provide a local alternative to conventional charging means, and could also enable more households to have access to electricity. Battery power can be used to provide lighting for child and adult education and access to improved communication, media and health services. Conventional charging methods involve travel to the nearest charging point, often miles away in the nearest town. Battery chargers connected to micro-hydro plants have demonstrated the popularity of this method to extend electricity services to those unconnected to the grid. Wind generators also have a proven record of providing power for battery charging in many areas, most notably in Mongolia and Inner Mongolia. A large part of the success of the technology appears to be the appropriate local design and adaptation of the systems, which are elements that are emphasised in this project.

1.1 Country Background

Peru is located in the west central part of South America; its capital and largest city is Lima. Peru is divided into three main geographical regions: the Coast, a narrow and mainly arid area next to the Pacific Ocean; the Sierra, covering the Andes area; and the Jungle, a flat, hot and humid area covering the Amazon region. Economic development has been hindered by the country's very poor transportation network, which has left large blocks of Peru isolated. Peru has a population of 24 million inhabitants, 30% of whom are in rural areas.

With a population of 18.3 million (1996), **Sri Lanka** is one of the most densely populated amongst the fifty poorest countries of the world. Sri Lanka is a predominately rural country, with only 18% of the population living in urban areas. The rural population is distributed over 25 000 villages, of average population 500.

1.2 Project Background

Six million rural inhabitants in **Peru** do not have access to electricity. Rural electrification in the coastal areas is much greater than that provided to the highlands which in turn is greater than that provided to the jungle areas. The use of batteries and subsequent charging is becoming more and more popular as a solution to the lack of electricity in small rural areas and among dispersed rural inhabitants. However, the great drawback is the high cost of the recharging services.

In Peru, photovoltaic systems can have serious deficiencies when compared to small wind systems with respect to power generated and costs. However, the main disadvantages of wind generators in comparison to other alternatives is their technical vulnerability, mainly involving their rotating components and their dependence on the availability of wind. Following closer analysis however, it is possible to overcome these disadvantages by using adequate technologies and materials. Additionally, the local manufacture of these systems will provide wider access to services and spare parts that will provide reliable operation and maintenance of the equipment used.

By 1996, **Sri Lanka** had achieved an overall household electrification rate of 42%, with a figure of 73% in the Western Province and figures ranging from 26 to 38% in the eight remaining, predominantly rural, provinces. Electricity consumption per household varies from 187 kWh per month in the capital city of Colombo to the average of about 50 kWh per month in the provinces. As is the case in many developing countries, the high cost of extending the grid to rural areas and low incomes from tariffs deter the utility responsible, in this case the Ceylon Electricity Board, from extending the grid in the short or medium term.

Households in unelectrified villages in Sri Lanka also use automobile batteries to power radio and TV sets. The number of such batteries is often quoted as 300,000. In a typical village kerosene is widely used for lighting and households will spend Rs.45 to Rs.75 per month on kerosene (~40p to 70p) if there are no alternatives. Batteries (60 or 90Ah), which are mainly used to power radio sets, are generally re-charged once a month at a cost of Rs.30 (~27p). Those using the battery for the radio and TV tend to re-charge them twice a month.

2. THE WIND REGIME IN PERU AND SRI LANKA

In **Peru**, the most interesting zones in the country with respect to wind potential are all of the coastal regions and part of the highlands, especially on the southern high plateau. Areas with the greatest wind resources are:

Coast: Tumbes, Piura, Lambayeque, La Libertad, Ancash, Lima, Ica, Arequipa, Moquegua and Tacna.

Andes: Cajamarca, Huanuco, Junin, Ayacucho and Puno.

In Piura, one of the regions chosen to base pilot studies, wind data reveals significant wind energy potential, with average wind speeds exceeding 5m/s. In Cajamarca, studies have indicated average peak daily wind speeds greater than 6m/sec.

In **Sri Lanka**, the wind energy potential has a considerable spatial variation across the country. The region from Hambantota - Sevanagala extending up to Yala in the South and the region comprising Puttlam-Mannar-Jaffna-Trincomalee (covering the North West, North and North East) are among the potential ones where small wind battery charging systems might find a market. As a typical example, the wind regime as observed in Hambantota on the south-eastern coast is shown in Figure 1.

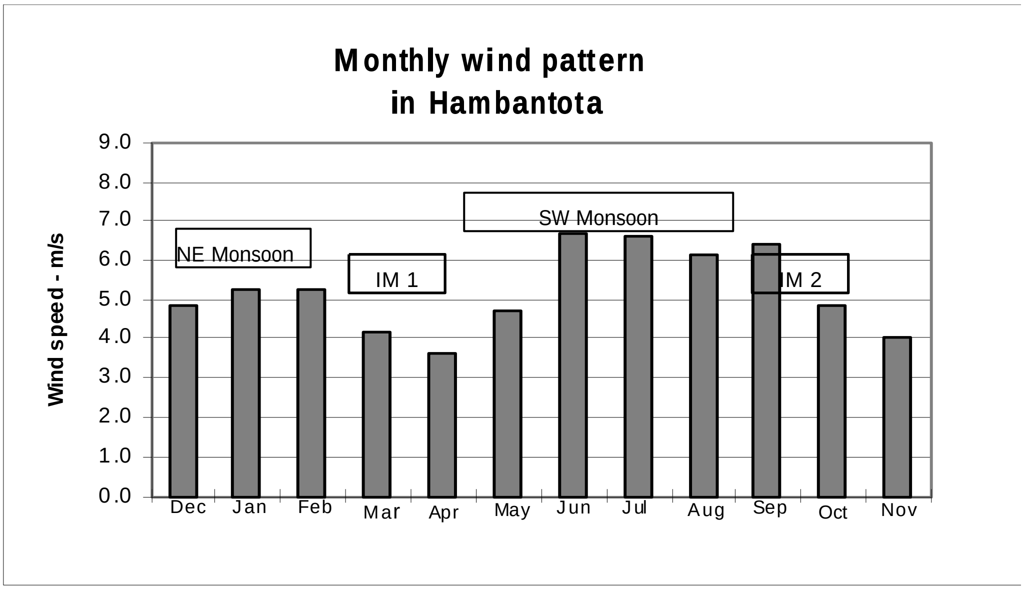

Figure 1. The wind regime in Hambantota

3. AN ASSESSMENT OF THE MARKET

In order to assess the potential market for wind generators in both countries villages were selected in which to carry out market surveys, based on the following criteria:

- No access to grid electricity.
- A significant proportion of households already using automobile batteries.
- No immediate plans to extend the grid to the village.
- Adequate wind energy resources.
- Disperse population.

Peru

Based on these criteria the zones of *Ayabaca* in Piura, and *Tembladera* in Cajamarca for the market study.

Ayabaca

The families involved in the study currently use diverse sources of energy, such as kerosene, burners, dry batteries and car batteries:

- The use of these energy sources is mainly related to domestic lighting using kerosene burners, candles and kerosene lamps. Additionally the inhabitants use dry batteries for communication means especially small radio transmitters and/or recorders.

- The use of kerosene is most common for domestic lighting purposes, all of the families used it in kerosene burners. Dry batteries are also very common both in communications and for torches.

- 25% of the families surveyed use car batteries to run radios and/or recorders; this shows that the inhabitants are familiar with this energy source although it is not yet used for lighting.

- 88% of the total form the low-income level group. They have a monthly average income per family of US$30.0 (~£19), while their expenditure on energy for lighting purposes, reaches US$ 2.0

(£1.20) per month. The main expenditure is commonly on food; other basic needs like health and education are provided by government.

Tembladera

As in the case of Ayabaca, the families living in this zone currently use diverse sources of energy:

- Generally, candles (42%) and kerosene lamps (89%) are used for domestic lighting. Additionally the inhabitants use dry batteries and car batteries to run some home appliances such as radios, recorders and TV, etc. In some cases diesel motors are used to run some equipment.
- Inhabitants consider the quality of their home lighting important, as 89% use kerosene lamps in their homes.
- The use of car batteries is also common with 62% of the interviewed families using these for radios, recorders and TV. Two families use diesel motors to run diverse home equipment.
- 35% of the total make up the low level income group with an average monthly income of US$ 45.5 (~£28), while their expenditure on energy, mainly for lighting and communications purposes, reaches US$ 2.4 (~£1.5) per month. Most of their income is spent on food in order to survive; any remaining income is spent on health and education services.
- 38% of the total make up the intermediate income level group with an average monthly income of US$90 (~£56). This amount is less than the official monthly income level established by the government. The average monthly expenditure made by these families on energy reaches US$ 6.5 (~£4) per month.
- 27% of the total make up the upper income level group with an average monthly income of US$210 (~£130) and an average monthly expenditure of US$13 (~£8) made on energy. The diverse energy sources used are mainly for home lighting and communications.

Sri Lanka

Based on the analysis of wind energy potential four villages were selected for the market survey - two in the Chilaw area, and two in Suriyawewa area. The profile of three of these villages is shown in figure 2.

Figure 2. Summary of Survey Data in Sri Lanka.

	Mahagalwena (Suriyawewa)	Muthapanthiagama (Puttlam)	Periappaduwa (Puttlam)
Existing lighting	Kerosene and dry batteries	Kerosene and dry batteries	Kerosene and dry batteries
Monthly Expenditure/HH	Rs280 (8%)	Rs290 (6%) [mean}	Rs290 (6%) [mean}
Percentage using auto batteries	67	71	65
Battery cost	90Ah Rs3400, 60Ah Rs3400	90Ah Rs3400, 60Ah Rs3400	90Ah Rs3400, 60Ah Rs3400
Average daily electrical consumption	70Wh	73Wh	58Wh
Charges/mnth	2	2	2
Journey time/charge	2hrs 40min	1hr 30mins	50mins
Cost per recharge	Rs40-45	Rs30	Rs35
Cost for dry batteries/mnth	Rs150		
Willingness to pay	Rs3000 initial, Rs400/mnth		

The willingness to pay for electrical services from wind generators was in the region of Rs. 3000-5000 (£27-45) as an initial payment, and Rs.500 (£4.50) per month. This would make a wind generator affordable if a loan covering 60% of the capital coast could be taken out.

4. THE SIZE OF THE MARKET

In **Peru**, the number of households without electricity that could potentially benefit from the use of wind generators is given below:

Departments on the coast	142,000
Departments in the highlands	38,000
Total	180,000

Although this total represents the market potential, it is still necessary to determine the number of families that would be able to purchase or acquire a small wind generator. To do this analysis three cases were considered in which the cost of the wind generator was £300, but other factors were varied, such as the potential wind regime and the cost of borrowing money. This cost may be difficult for the very poor to afford if they want to have their wind battery charger to be of exclusive use for the family. However, it may be possible to establish a small business of battery charging for their neighbours. They may be in able to break even after two years.

There appears to exist considerable demand for electrical services that could be met by wind generators in the coastal areas of **Sri Lanka**. These are the unelectrified fishing villages with total population possibly well over 60,000 households. Even if only 5% of these households purchase wind generators (and the indication is that the figure could be much higher), that represents a potential market for 3000 wind generators. Three possibilities for the use of batteries were considered in Sri Lanka:

a) Community battery charging to meet present practices for use of battery. Average daily demand is 67Wh.
b) Community battery charging with additional use of the battery for lighting.
   The type of lighting considered is 8W fluorescent tube lights. Four hours of lighting would give a demand of 107Wh, eight hours of 147Wh.
c) Individual Ownership

5. TECHNICAL SUMMARY

The two countries set different standards of efficiency for the alternator. The same physical construction is being used for both machines, but there are differences in the detailed electrical design, reflecting these different priorities. In the case of Sri Lanka, the alternator has a fairly low efficiency, but a very good speed range, and a good matching to a rotor speed/power curve for a 2 metre diameter rotor. A better alternator efficiency has been obtained for the Peruvian version, but at the expense of low speed performance in light winds. An electronic circuit which changes the coil connection configuration between high and low windspeed modes has been developed to overcome this problem, but it remains to be seen whether this approach is practicable in the real world. A detailed description of the Sri Lankan machine follows.

The Sri Lankan alternator is designed to operate at speeds 165 to 300 rpm and produce rated net output of 100 watts at the battery, but this is not the limit of its output capability. Output to the battery of 200-300 watts is quite feasible. Alternator efficiency drops for the higher outputs, but the wind is free, and extra output may be useful, if the load can handle it. Charging neighbours' batteries during windy periods would be one application.

Materials chosen are readily available in Peru and Sri Lanka, and manufacture is simple. The design is at the prototype stage; product development for the market will take place locally. There are eight magnets on the rotor but only six coil assemblies in the stator. This arrangement results in a phase difference between the coils, giving 3-phase electrical output. 3-phase is desirable because it provides smooth power output. A comparison of the generator specification for both countries is shown in the table below:

Table 2. Comparison of Generator Specifications

Item	Peru	Sri Lanka	UK
ROTOR			
No of blades	3	3	
Tip Speed Ratio	5	5	
Length of Blade (m)		0.6	
Rated Power (W)	100	100	
Rotor Diameter (m)	1.7	1.7	
Rated Wind Speed (m/s)	6.5	8.0	
Rotational speed at rated windspeed (rpm)	380	450	
Max. Cp	0.35	0.36	
Cut-in Windspeed (m/s)	3.5	3.5	
Rotational Speed at cut-in (rpm)	220	200	
Cut-out Windspeed (m/s)	13	14	
Tower Height (m)	12	12	
Aerodynamic Control		Hinged Side Vane	
Estimated Price (£)	300	200	
GENERATOR			
Type			Permanent Magnet, axial air gap
Rotor			Magnets surrounded by resin and glued to steel discs
Stator			Coils encapsulated in fibre glass
Cooling			Air-cooled
Max. power output			200W

6. A COST COMPARISON OF SMALL WIND GENERATORS AND REALISTIC ALTERNATIVES

Some analysis has been conducted in Peru and Sri Lanka concerning the cost of the proposed generators compared to alternative options. In Peru the most realistic alternative is solar photovoltaics; in Sri Lanka the cost of diesel generators and kerosene lighting was also considered. In the case of Peru, the estimated equivalent cost of the wind generator and tower (pre installation) is around £300; in Sri Lanka around £200. Differences are primarily due to local labour rates. The system lifetime was estimated to be 20 years

In Peru the cost per kWh of the proposed generator ranges from 13p to 72p, depending on the wind regime, while a solar home system would cost 76p/kWh

The main findings in Sri Lanka are that the projected energy cost will be between 63 – 91p/kWh, depending on the wind regime, which is slightly less than current prices of grid recharging. The study shows that, on an economic basis, wind generators are broadly comparable with, or marginally cheaper than, solar home systems and current battery charging practices, with the wind generator being the least cost option if the capital cost is low. A diesel generator-powered micro-grid is the cheapest option; however, this would require community mobilisation not necessary in the case of the individual ownership of wind generators.

7. CONCLUSIONS

The wind potential in **Peru** is not as attractive for the exploitation of wind energy systems for the grid as it is for small systems, but there are enough good resources that can properly used for the benefit of isolated rural people. The wind generator has been designed with the local manufacturing capacity in mind but there will initially be the need to import bearings and magnets. The wind battery chargers could compete with other energy options, provided the wind resources exist. The cost per kWh generated with this wind battery charger can provide cheaper energy than with PV in all cases considered. The 100W unit designed in this project is meant for family purposes and for very small battery charging businesses. It will be necessary for the poorest to have access to appropriate credit to afford a system; otherwise they could benefit from the services provided by neighbours.

In **Sri Lanka**, the widespread use of automobile batteries, involving transporting them over long distances to charging centres, shows that there is strong demand for electrical services. The growth in grid connected households is high (over 3% per annum), although there are still many villages that will probably not be electrified for many years.

There appears to exist considerable demand for electrical services that could be met by wind generators in the coastal areas of Sri Lanka. These are the unelectrified fishing villages with total population possibly well over 60,000 households. In comparison to other options, wind generators appear to provide the most economical means of accessing a higher level of electrical services (for the target group of battery users) if individual or small group systems are considered.