THE ECONOMICS OF RURAL ELECTRIFICATION IN A DEVELOPING COUNTRY

By

KARL F. SEHEULT

SYNOPSIS:

This Paper examines the economics of the operation of a public electricity supply system and in particular the economics of the extension of supplies to low population density areas in a developing country. It examines some of the financing arrangements used in the Caribbean and indicates some possible approaches. It describes also the role of the Engineer in assessing and finding the means to resolve some of the problems of improving the economy and raising the standard of living in a developing country through the expansion of the public electricity services.

THE BASIC ECONOMIC PROBLEM OF ELECTRICITY SUPPLY:

Any public electricity supply system is faced with the basic problem of generating enough revenue to pay not only for its recurrent operation and maintenance charges but also for provision of an appreciable part of its own development funds.

The electricity supply industry is peculiar among public utilities in that it requires very large amounts for capital development in comparison to its operating costs. On the other hand, electricity tariffs must be kept low enough to meet competition from other forms of power such as gas or oil and to encourage the use of electricity in order to build up the loads and load factors to keep operating costs down. It must also spend enough money in its operations to provide a sufficiently reliable supply to encourage the use of electricity, particularly in industry.

As an industry, it is unique, by virtue of the fact that its product cannot be stored and must, therefore, be produced in the quantities required at the instant of requirement. This means, in effect, that it must have plant capable of producing at a rate equivalent to the greatest instantaneous cumulative demand made by its customers. In other words its capital investment, and, to a great extent, its establishment depend on the demand and not on

the number of units used by customers. It is obvious, therefore, that the load factor (the ratio of its maximum demand to its average demand) is a very vital factor in determining the cost of producing power. This becomes even more vital in a country like Trinidad & Tobago where the fuel cost, which depends entirely on units used, is low and where plant costs tend to be high. The supply authority, therefore, aims to encourage those customers who use energy at a constant rate and to discourage those customers who use large blocks of energy for very short periods. This is why energy rates to industries which run on a 24-hour basis are much cheaper than energy rates to domestic installations which tend to use electricity mostly during two short periods in the day around midday and early evening.

In order to provide reliability of supply duplication is often required. This could mean duplication of generating plant, and of distribution and transmission systems including sub-stations, transformers and switchgear. Extensive duplication could, of course, involve very considerable expenditure and would only be justified where the loss of supply to a customer would have a very serious effect on the economics of the customer's operations. The supply authority could only justity this expenditure in cases where because of a customer's use the revenue accrued would be considerable. A high degree of duplication is normally only justified for a very large customer where even a short shut-down of the supply could entail very heavy financial losses. This applies in many chemical industries where a shut-down of less than a minute could involve many hours of delay in production, or in a glass works, for instance, where tons of molten glass could become solid and require many hours of work before operations could be resumed.

In a high population density area, such as a big city, particularly where there is considerable three-shift industry, the economic problem is insignificant and there is little difficulty from an economic point of view in providing a very reliable supply at a very low cost. In less densely populated areas such as farming areas where there is a minimum of industry the problem becomes significant and needs a much more careful approach.

THE PROBLEM IN A DEVELOPING COUNTRY :

Generally speaking, one does not find in a developing country any large, very high population density areas such as one finds in a more highly developed country where there are large cities with numerous multi-storey buildings and considerable industry. There are usually few towns of any size, and the greater part of the distribution system comes where the per capita income is very low. On the other hand, there tends to be a great need to avoid the migration of population to the towns with its resultant creation of slums, unemployment and other social problems. Usually there is also a great need to provide for agricultural development and therefore to provide

both the amenities in the agricultural areas and the means for some mechanisation of agriculture to make it more attractive and remunerative. There is also a need to improve the general health and living conditions of rural inhabitants and to have a citizenry practised in democratic ways of life with access in their own homes to the principal means of communication, i. e. radio, Television, etc.

The problem of electricity development in a developing country is frequently accentuated by the lack of funds for capital development. A developing country usually needs funds for the development of roads, water, education, etc., and is hard put to find the large amount of funds necessary for electricity development. On the other hand, unless the rural communities can be provided with the amenities of good roads, a good water supply and a good electricity supply, development in agriculture and small industry is stagnated and the economy and standard of living do not improve.

The problems of electricity extension in rural areas in any part of the world are appreciable. In a developing country they are formidable.

THE ECONOMICS OF RURAL EXTENSION:

The problem of extending distribution lines can be reduced to a simple one of obtaining sufficient revenue per mile of line to justify the expenditure of building the line; of generating and transmitting the energy to each customer along this line and of collecting this revenue. It is generally accepted that an electric utility in order to generate sufficient funds for a reasonable proportion of its own capital development and also to pay for its own expenses, must have an operating ratio of not more than 70%. "Operating ratio" in this context means the ratio of all expenditure, excluding interest on borrowings, to total revenue. This ratio is required by the International Bank for Reconstruction and Development where it loans money to Electric Utilities for development.

To establish this ratio for each individual area examined, it would be necessary to know the amount of electricity that would be sold, the load factor at which the sales would occur, how the time of maximum demand of the extension would fit into the general system demand and the cost of making the extension. To make use of these figures when obtained it would be necessary not only to know a great many average costs leading up to the various tariff charges but also a second set of averages showing the proportional effects of units of variance. To estimate the effects of each extension on this basis would involve a great deal of engineering and accountancy work which would depend, in any case, on the accuracy with which the initial forecasts were made. In view of the difficulty of making accurate initial forecasts such work could not be justified and it is necessary to find some simple method of reasonable accuracy that could be applied by relatively untrained personnel and understood by the average customer.

The parameters easiest to establish are the capital cost of the extension and the estimated revenue that each will bring. Of these two figures it is easier to obtain the capital cost of the extension than the revenue. With a required operating ratio of 70% and figures for revenue and expenditure it is possible to obtain a required minimum revenue as a percentage of the capital cost of the extension. Because of the fact that the revenue will tend to increase rapidly over the first few years and then level off, it is normal in Trinidad to take the revenue estimated for the fifth year. The trends of domestic consumption in Trinidad between 1953 and 1957 show generally that by the fourth year the increase of consumption in a new extension has steadied down to about 10% or 15%. The problem remains of estimating the revenue at the end of five years.

In 1956 a firm of Research Consultants carried out surveys on behalf of the Trinidad & Tobago Electricity Commission in two areas which had been on electricity supply for some time to determine the use of electrical equipment. Table 1 indicates the result of this survey.

Again in 1959 the same firm undertook a study to determine the amount of money spent by householders in non-electrified far-flung rural areas on functions that could be performed with electricity such as lighting, ironing, cooking and radio. The survey was undertaken in two sample areas both in sugar farming districts. Table 2 indicates the result of this survey.

From Table 2 it can be seen that there was an average of $46.00 a year being spent by rural householders, not in an electricity supply area, for cooking, lighting, ironing and radio batteries in the lowest income group area and $55.00 in a slightly higher income area. Tables 1 and 2 give an indication of the type of revenue that could be obtained and the potentials of the area if an electricity supply were made available at a price that could complete with present methods of lighting, cooking, ironing, and battery radio entertainment. Upon such information is based an average revenue per customer in low population density areas.

The number of customers in existence on the route of any proposed line is easily established, but it is normal when electricity and water and reasonably good access are available in any community for a tendency towards increased building activity. It is normal, therefore, depending on the particular lay-out of the area to provide for some additional new houses to be supplied in the five-year period.

The establishment of the cost of making the extention is, as previously mentioned, relatively simple. On the other hand, there is much scope to reduce the present unit cost of constructing distribution extensions. The economics of rural extension can, therefore, be improved either by reducing the cost of distribution extensions or by increasing the revenue.

TABLE 1

THE USE MADE IN 1956 OF DOMESTIC APPARATUS IN TWO FAIRLY PROSPEROUS SAMPLE AREAS

Surveyed Sept./Oct. 1956 by D. M. Searl Associates	RURAL				
	Curepe Sangre Grande		Couva California		Overall
	A $10-$100	B over $100	A $10-$100	B over $100	
Method of Cooking	%	%	%	%	%
Electric	—	7.5	3.7	9.5	3.7
Progas	—	32.5	—	4.8	7.4
Pitch Oil	60.0	45.0	31.5	66.7	49.3
Wood	21.4	7.5	38.9	—	21.2
Coals	18.6	7.5	25.9	19.0	18.4
Apparatus Used					
Refrigerator	10.0	75.0	1.8	38.0	24.8
Radio	51.4	82.5	35.1	80.9	56.6
Iron	44.2	72.5	55.5	90.4	53.5
None	28.5	2.5	27.1	—	19.2

TABLE 2

SUMMARY OF EXPENDITURE FOR DIFFERENT INCOME GROUPS IN SAMPLE AREAS (MADE IN 1959)

	Mount Pleasant Sample of 64 houses visited out of a total of 256		Carytal (All 62 houses visited)	
	No.	Mean Yearly Expenditure $	No.	Mean Yearly Expenditure $
Use only wood for cooking	45	44	51	41
Use only Pitch Oil for cooking	19	81	11	71
Income Group - A	0	——	0	——
B	4	84	0	——
C	26	64	19	54
D	34	43	43	42
TOTAL	64	63	62	46

COST OF MAKING EXTENSIONS :

In order to keep the cost of making extensions to the distribution system into the rural areas as low as possible, the cheapest type of construction commensurate with reasonably reliable service is used. This inevitably means overhead line construction, making use of relatively cheap wooden poles and wherever the load density is low enough the use of single phase distribution lines. A common neutral is used for both High Voltage and Low Voltage distribution in conjunction with the simplest possible arrangement of transformer and protective arrangements. Protective arrangements are usually confined to fuses or in larger areas to pole-mounted auto-reclosers, sectionalisers or combinations of these with fuses.

Supplies are usually made on spur lines with no provisions for alternative supplies, and the most popular voltage for High Tension distribution is in the 11 kV/13.2 kV class which gives reasonably low costs with reasonably good area of distribution. Conductors are almost inevitably steel-cored aluminium, although some galvanized steel has been used on extremely lightly loaded single phase rural lines, in some cases, with earth returns. Earth returns offer a possible saving in costs but only where overhead telephone lines do not exist, otherwise the interference problem usually becomes insurmountable.

One of the high cost factors in overhead line rural distribution is the cost for compensation paid for crop trees cut down on estates. The cost of building a straight overhead line is of course considerably less than building one with many angles, and a careful assessment has to be made of the relative savings of running lines across country against the higher compensation costs involved when one leaves established traffic routes. The economics obviously depend on the kind of crops which have to be destroyed in building a straight line across country. The question of supply to houses along the road is of course of prime importance in such cases.

All the above arguments have been based on taking electricity to rural areas from a central electricity supply. In remote areas there are, of course, alternatives which might be more attractive economically. In Trinidad, for instance, there is the possible alternative of using waste natural gas at low pressure in distant isolated districts. Much development has also been done recently in Europe on micro hydroelectric units, some as small as 25 kW. These units need very little expenditure in civil works and require only a reasonable quantity of water at heads of 40 feet or even less. The cost of such a unit is about $35,000 US which would be the equivalent of about four miles of overhead line where the compensation costs are average. The cost of operating and maintaining such small micro hydro-power units is quite low and in areas that need the erection of a few miles of line through totally uninhabited country to reach a settlement, such a scheme offers distinct advantages. The units are completely self-regulating and therefore need no attendance other than periodical inspection and maintenance.

BUILDING OF LOAD:

Other than trying to keep the cost of installation as low as possible the only other way to improve the rural extensions is to make the revenue as high as possible. This entails doing everything possible to have potential customers connected to the supply as soon as the line is constructed and getting them to make the maximum use of electricity.

One of the problems of rural electrification is the lack of ready funds on the part of the people who wish to be connected to the supply. Unless some help is given it usually takes anywhere from two to five years for the potential customer to collect sufficient money to have his premises wired. To remove this problem both Trinidad and Puerto Rico have embarked on an Assisted Wiring Scheme whereby the Electricity Supply Authority pays for the wiring of the house and collects this sum back from the customer over a period of three or four years. By taking large groups of customers and obtaining tenders for large blocks of houses the cost of wiring per house can be considerably reduced. For instance, in Puerto Rico the cost of wiring per house has been kept down to $30 US ($51TT) and in four years nearly 40,000 premises have been wired under the scheme. In Trinidad & Tobago assisted wiring was started in August, 1961, and in four years 2,446 premises have been wired under this scheme at an average cost per house of $60 TT.

Having got the customer's house wired and the customer connected to the supply it is essential to encourage him to install as many electrical appliances as his resourses will allow. In the survey previously mentioned customers in Mount Pleasant and Caratal who use kerosene for cooking spent between $71.00 and $81.00 per year. It is not too difficult to sell electric cooking to such people, provided that a cheap and reliable cooker is available. Those, however, who use wood for cooking would find it very difficult to find the additional funds for electric cooking. The replacement of battery radios by mains operated radios is never any problem, neither is the provision of electric lighting. Ironing by electricity is relatively easy to sell with an active sales force, but refrigerators still tend to be too high in first cost to find a wide-spread market amongst the lower income groups. The same problem exists in selling appliances as exists in wiring houses but long-term credit in the form of hire purchase can remove a great deal of this problem. There remains scope for very much more house to house sales in the very rural districts but particularly there is need for the introduction of a type of appliance with all the "frills" removed so that the cost price is brought within the reach of the lower income groups.

The economics of rural extension can be considerably improved by the use of co-operatives to install such things as electrically-operated crop dryers and refrigeration facilities for fishing which the individual small farmer or small fisherman could not afford. A real necessity is the orderly development of rural amenities to prevent a dispersal of houses and small industry to make the distribution of water and electricity and the provision of roads at a much

lower cost per house. Far too little co-ordination of the efforts of road builders, water authorities and electricity authorities now exists. The ideal arrangement would be for the very small village to retain its rural outlook, to put the farmer close enough to his farm to operate it successfully and still give some of the advantages of the economics of a higher population density distribution.

FINANCING:

With all the effort of load building and of reducing the initial costs of distribution there still will remain many areas where the revenue to be obtained is insufficient to justify the expenditure of funds on the capital works. The only solution here, of course, is either direct subsidies from the Central Government or "Soft Loans" or both. In Puerto Rico, for instance, their rural electrification programme is divided into two parts. One part covers those areas that can justify the expenditure on the extension of the supply and where the Power Company can require the potential customer to guarantee a consumption which would make the extension economic or alternatively pay a capital contribution in cash that would have the same result. The other is for those areas where the customer can neither guarantee a sufficient supply nor provide a capital contribution. In such cases, the Central Government of Puerto Rico reimburses the Electricity Authority for any loss they may suffer, and also provides loans at very low interest rates to the Electricity Authority. By this means Puerto Rico has succeeded in virtually complete electrification of its rural areas.

In Trinidad & Tobago, the practice so far has been followed in requiring capital contributions either in cash or in free labour or in waivers of compensation rights in districts where the extension could otherwise be uneconomic. No outright Government cash subsidies have so far been provided. The alternative to outright subsidy is the so-called "Soft Loan" where only nominal interest rates of about $\frac{3}{4}$ to 1% are paid and where there is a moratorium on interest or capital repayment for about ten years with about forty years for capital repayment. The effects of a loan of this type on the finances of an extension are shown in Table 3. From this it can be seen that in Trinidad the effect of such loans would be to enable about 93% of all rural areas to be electrified economically.

Failing Government subsidy and "Soft Loans" the only approach that remains to an Electricity Supply Authority is to supply those areas that give the best return on capital expenditure. By this means the greatest amount of funds for capital expansion accrue and by constantly applying these funds to areas with the highest rates of return, borrowings are kept to a minimum and the greatest number of rural extensions can be carried out without any

serious effect on the economics of the whole organisation and, therefore, on the electricity rates. This, however, means that low population density areas have to wait a long time to get an electricity supply and this is not always politically acceptable. This latter arrangement also means that it takes longer to electrify the whole country.. On the other hand it has the advantage of maintaining steady employment for a longer period with a slight tapering off, whereas if electrical extensions were carried out more rapidly there would be a consequent sudden reduction of employment on capital works when saturation point was reached.

THE ROLE OF THE ENGINEER IN THIS DEVELOPMENT:

The sensible evaluation of the economic and other factors which set the pattern for an orderly and efficient expansion of an emergent country's rural electricity development requires the attention of men trained in engineering principles.

The necessity for finding less expensive and yet reliable ways of constructing extensions to the distribution system is a necessity if developing countries are to expand their electricity systems to enable their populations to enjoy a reasonably high standard of living and to improve their economy by the encouragement of small and medium industries. A great deal has been done during the past decade but a great deal more can still be done to find cheaper and better ways of carrying electricity to those thinly populated areas.

As mentioned before the development of micro-hydro power units which has taken place in Europe in recent years has made it possible to carry electricity to very remote areas. The installation of completely remote-controlled isolated units making use of waste energy in the district can also make the difference between an area having electricity or not, but the cost must be kept at a reasonable figure without any serious reduction in reliability.

There is a great need to provide simply-designed domestic electrical appliances, at a cost within reach of the low income rural dweller. The same necessity exists to reduce the cost of refrigeration facilities for the small fishing community and mechanised electrical equipment for the small farmer.

A great deal can and must be done now and in the immediate future. Engineers with the right outlook and training are urgently needed in increasing numbers to evaluate the problems of a developing nation and to find successful and expedient solutions.

TABLE 3

SOFT LOANS AND SUBSIDIES REQUIRED FOR LOW REVENUE PRODUCING AREAS

Customers %	Capital Cost $	Return on which Revenue computed %	Income Derived $	Capital Cost for 12½% return $	Capital Cost for 23% return $	Soft Loans available 45% of Capital Cost $	Subsidy required Soft Loans Available (2-5) $	Subsidy required No Soft Loans Available (2-6) $
72	22,400,000	27	6,048,000	—	—	—	—	—
21	9,938,028	17¾	1,764,000	—	7,669,565	4,492,112	Nil	2,268,463
7	5,760,000	8¾	504,000	4,032,000	2,191,304	2,592,000	1,728,000	3,568,696