Rural electrification in Tanzania: constructive use of project appraisal

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Rural electrification in Tanzania

Constructive use of project appraisal

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Three ways of evaluating rural electrification projects are described: the financial appraisal, the economic appraisal and the socioeconomic appraisal. These appraisals are respectively from the point of view of the electric utility, the national income and the national welfare. Past experiences with project appraisal in Tanzania are critically assessed. A methodological framework for improved project appraisal is presented with emphasis on socioeconomic benefit measurement. The three types of appraisal are applied in a constructive way to a Tanzanian case. Measures are formulated to solve the main bottlenecks, being ineffective electricity tariffs and low power factors. Copyright © 1997 Elsevier Science Ltd.

Keywords: Rural electrification; Project appraisal; Tanzania

In order to solve rural energy problems and to increase the quality of life in its rural areas, the Tanzanian government puts great emphasis on the role of rural electrification. In this respect the policy document (TANESCO, 1989c), which has been made by the state owned Tanzania Electric Supply Company (TANESCO) in 1989 can be considered as the most recent documentation of the comprehensive objectives and priorities of TANESCO and the government of Tanzania. In this document the following socioeconomic objectives of rural electrification are mentioned:

1. avoiding deforestation by means of substitution of hydropower based electricity for present non-sustainable firewood consumption;
2. improving rural energy supply by sending power to isolated areas;
3. promotion of performance of agro-based industry;
4. establishment of a base for small scale industries;
5. improving the standard of living in the rural areas; and
6. improving the situation for women.

The impacts which have been achieved up to now appear to be quite disappointing, as indicated in a recent study with respect to rural electrification in Tanzania (Kjellström et al., 1992). Very moderate success could be recorded in the improvement in the quality of life, with respect to improved health care quality, improved security and improved employment for women in the commercial sector. Because of the limited switch from fuelwood to electricity for cooking in electrified areas, rural electrification had hardly any impact on deforestation. Rural energy supply in general was only marginally improved because up to now only 44% of the district headquarters and less than 1% of the 8600 rural villages have been electrified. Therefore, the progress of
rural electrification in Tanzania, which started in the early 1970s, can be called very modest. Finally, no expansion of agro-based industries or small scale industries in townships was identified in electrified rural areas.

In the study mentioned above the suggestion is made that a more intensive use of economic cost–benefit criteria in the ranking of projects could improve the performance of rural electrification in future (Kjellström et al., 1992).

Past experiences with cost–benefit analysis in rural electrification projects in Tanzania, as discussed in the following section, show important failures and shortcomings. Therefore a different approach is needed. The objective of this article is to develop, discuss and apply a better approach based on a general theoretical framework with respect to rural electrification project appraisal.

First, some experiences in Tanzania with rural electrification project appraisal are described. Thereafter, a theoretical framework is discussed for constructive appraisal of rural electrification projects with the focus on socio economic benefit measurement. This framework is adapted to Tanzanian circumstances and applied to a rural electrification case in Tanzania. Finally, conclusions are given on the theory and the results of the application to the Tanzanian case.

Past experiences in Tanzania with rural electrification project appraisal

Project appraisal studies with respect to rural electrification in Tanzania, which have been made during the last ten years, almost without exception show a positive financial outcome or at least favourable impact for the national economy. In actual practice, however, the exploitation of rural electricity networks are loss-making and can only be maintained through cross-subsidies. This makes one suspect that there is something wrong with the general approach of project evaluation.

Documents concerning rural electrification reveal various questionable basic assumptions and calculation methods. Remarkable facts from the rural electrification policy document (TANESCO, 1989c), which gives the guidelines to be used in the appraisal of electrification projects, are:

1. Appraisals are limited to macroeconomic impacts of electrification projects, which completely ignores TANESCO's own financial interests;
2. Non-quantifiable benefits are said to be compensated for by a 'social discount rate' which is set lower than the normal discount rate. No indication is given how the value of such a social discount rate should be determined;
3. When calculating the macroeconomic benefits only cost savings and productivity increases of the industrial sector are considered to be quantifiable. Since benefits which are thought not to be quantifiable are only marginally dealt with, additional benefits because of increased quantity or quality of end use are grossly ignored. These benefits can be considerable especially where households are concerned.
4. When determining the demand, forecasting factors are mentioned which influence electricity demand, but no indication is given which method should be used to estimate the final electricity demand.
5. In a discussion of the supply system design, certain standard conductor sizes are suggested for certain voltage levels without mentioning the need to assess different cases by means of load flow analysis.

The absence of a suitable framework for project appraisal becomes clear when looking at feasibility studies made by TANESCO:

1. Studies have been made in which financial revenues of the electric utility have been interpreted as macroeconomic benefits (TANESCO, 1989b);
2. In another study macroeconomic benefits were represented by shadow electricity prices (per kWh), without mentioning how these were determined (TANESCO, 1989a). The problem of not knowing the background of such a calculation becomes clear if one notices that in another study (TANESCO, 1987) costs for small scale diesel based power generation are used as a shadow price when calculating economic benefits for households. This leads to an overestimation of economic benefits, for an average Tanzanian household is not able to pay for the investment and operating costs of such a generator.

A recent study made by a Western consultant had a better financial framework, but here also shortcomings can be noticed.

1. The assumption was made that the project under consideration was supposed to be too small to have any impact on TANESCO's supply system (Kennedy and Donkin Power Systems, 1989). Therefore, only variable costs of hydro generation (estimated at US$0.004 per kWh) were used as bulk supply costs of power and energy. In this way the costs which have to be made by TANESCO are heavily underestimated. This is particularly strange since in the same study in the macroeconomic analysis marginal cost of grid supplied electricity were used of US$0.108 per kWh.
2. Electrification of a particular township is justified by stating that this would make a significant contribution to the economic and social benefits of the project without even trying to quantify the domestic contribution to the benefits.

The assumptions and methods mentioned do not all have the same impact on the results, but in general they lead to a systematic overestimation of financial and economic indicators.

Moreover, all appraisal reports only looked at making a judgement about the project under consideration, without properly pinpointing the underlying problems, identifying possible ways to solve them and comparing different means to reach a solution.
From these experiences it becomes clear that there is a high need for a suitable framework which allows for sound appraisals of electrification projects in a developing country context. It is also necessary to make an explicit distinction between the assessment on the electric utility level and the different possible assessments on the national level.

Theoretical framework

First, the overall theoretical framework for constructive project appraisal for rural electrification is discussed. Thereafter, we focus in on the topic of socioeconomic benefit analysis.

Constructive project appraisal

The need for an ex ante evaluation of projects is based on the fact that limited economic resources, have to be allocated in the best possible ways, especially in the context of developing countries. The decision to finance a rural electrification project implies that scarce resources used will not be available for some other purpose, such as a school or a hospital. Therefore, it is necessary to have criteria with which different rural electrification projects can be ranked and compared with other types of projects. A project appraisal can be useful both for the electric utility which has to make the investments and for the country as a whole. The electric utility, or any other agency which undertakes a rural electrification project, has to determine whether it is attractive to invest in the project under consideration compared with investing in other projects or not investing at all. Such an assessment will be called the 'financial' appraisal. From the perspective of the country as a whole an appraisal can be made directed at the maximization of the national income. Such an analysis is most commonly based on the value added of a project and will here be referred to as the 'economic' appraisal. However, it is also possible to look at the maximization of the welfare of a country. An assessment with such a goal will be labelled as 'socioeconomic' appraisal.

Criteria in a project evaluation which can be used to evaluate and rank projects are (among others) the net present value (NPV), the internal rate of return (IRR) and the benefit–cost ratio (BCR). These are all well established cost–benefit criteria (Munasinghe, 1987; UNIDO and IDCAS, 1986). In the financial, the economic and the socioeconomic appraisal these criteria are used in a comparable way but they represent different quantities which are based on distinct calculations.

If the cost–benefit criteria, as presented above, indicate negative results, this does not automatically mean that a project will not be implemented. Private utilities, for instance, may have cross-subsidization to subsidize rural electrification projects with a negative financial NPV. Also, a government (or government agency) can have other reasons than the ones presented by the outcomes of the feasibility study to electrify an area or to give support to its electrifica-
tion. An example might be that one wants to focus on rural development and therefore support rural electrification. In these cases, the project appraisal shows the economic price for the country as a whole or the financial costs for the electric utility when a negative project is undertaken anyway. In this way the decision makers can take their decision in full awareness of the magnitude of the financial and economic burden which the project causes.

The results of a cost–benefit analysis are not necessarily confined to go or no-go decisions. The analysis can be directed at identifying bottlenecks which threaten a successful implementation of the project. The project can then be adapted in order to avoid the thus identified problems. Project appraisal with this twofold task will be referred to as ‘constructive project appraisal’.

A characteristic for an appraisal of a rural electrification project is its multidisciplinary character. In the design step, financial subjects are interwoven with engineering topics, while social-economic problems play an important role in the measurement of socioeconomic costs and benefits.

The sequence of the essential steps in rural electrification project appraisal, as identified by many authors (Menon and Rao, 1986; Munasinghe, 1987; Siyambalapitiya et al., 1991), is systematically represented in Figure 1. From this scheme it can be seen that the activities which have to be undertaken are basically the same for all three appraisals as distinguished above. A common principle is that the difference has to be assessed between the situation in which the project will be implemented and the situation in which the project will not be implemented. The main difference between the three approaches can be found in the interpretation of what has to be considered as costs and benefits.

For the financial analysis one should include all costs and benefits for the utility which supplies electricity at prevailing market prices.

For the other two analyses the benefits and costs of all actors in a country should be looked at. In the economic analysis the benefits are the incremental economic revenues, in monetary terms, which result from the consumption of electricity. At the benefit side of the socioeconomic analysis not only monetary benefits, but all contributions to the increase of welfare are accounted for. For both assessments on the national level the cost side is the same, but different from the costs as calculated in the financial analysis: inputs, as far as national economic resources are concerned, have to be valued at their economic opportunity costs.

In the evaluations on the macroeconomic level, international transactions such as taxes and subsidies should be disregarded. International transactions should be included. Therefore, all services and goods should be priced by means of efficiency shadow pricing to determine their true economic values. This concept of shadow pricing is particularly important in developing countries, where generally many market distortions, like subsidies and taxes, are present. These distortions cause prices of goods and services to diverge from their true economic values. Methods of shadow pricing have already been explained and applied in other studies (Broek, 1993; Munasinghe, 1987).

From the activities as presented in Figure 1, the power market survey, the load forecasting and the supply system design are specific for an evaluation of electrification projects. Although the methodology and techniques for these activities are well established, they have to be adapted to specific circumstances. For more details on these items, the interested reader is referred to the underlying literature (Broek, 1993; Menon and Rao, 1986; Munasinghe, 1981; Munasinghe, 1987; Munasinghe, 1990; Siyambalapitiya et al., 1991; UNIDO and IDCAS, 1986). The step of the identification of bottlenecks together with the possible improvement (see Figure 1) is characteristic for the constructive approach in project appraisal.

The other steps in Figure 1 are well known from cost–benefit practice, except for the measurement of socioeconomic benefits. These are the benefits for the national welfare, which result from the electrification project. They include monetary and non-monetary revenues. This subject is rather complex and has been dealt with relatively rare in literature. Therefore this subject will be discussed here in more detail.

Socioeconomic benefit analysis

The starting point for the discussion of the theoretical framework will be the supply-demand graph in Figure 2. In this figure the stylized demand curves are presented for electricity (curve DE) and for the alternative energy source (curve D2), which is to be substituted by electricity if the electrification will be undertaken. Basically, these curves are only representative for one kind of electrical end-use. The quantities of energy used on both axes are given in units of consumed output. The graph represents the average behaviour of a single consumer in a group of consumers of the same type (for instance households). Assumptions made in this figure are:

(1) consumers that switch from an alternative source to electricity, switch completely;

1 As mentioned, the figure is stylized. This means that prices and quantities do not represent realistic values. The choices for the various points in the figure have been made, so that the principle can be visualized clearly. Therefore, one should not draw conclusions from the sizes of the areas in the figure. Connection charges are not included in the demand graph, for they are considered not to influence the consumption pattern (i.e. the demand curve) once a household is connected. They do, however, influence the amount of households that get connected to the grid, which is reflected in the load forecast. In this context the term ‘alternative energy’ does not refer to sustainable energy, but to the form of energy supply which is substituted by electricity, because of the electrification.

2 Some examples of this are: electricity for lighting and kerosene for lighting in kilo lumen hour, electric and diesel motors in the mechanical energy which is supplied by the axis and cooking in heat supplied to the pan. An alternative, but basically identical method, is used by Munasinghe (1987). The quantity of alternative energy consumed is represented here in the quantity of electricity (in kWh) required to produce the equivalent output (for instance a certain number of kilo lumen hour for lighting).
a switch to electricity increases the quality of the service, reflected by $D_E$ shifted outwards. In the situation that there is no significant increase in quality of the output, both curves overlap. This assumption does not influence the general principle;

(3) the price of electricity per consumed unit of output is lower than the price of the alternative energy source, reflected by $P_A$ being higher than $P_E$.\(^3\) This assumption will have no influence on the underlying principle which will be illustrated;

(4) the supply curves ($S_A$ and $S_E$ in Figure 2) are assumed to be horizontal lines, because it is believed that one single rural electrification project will not influence the marginal costs of electricity supply.

It should be realized that normally the shape of the two demand curves is not known. The only point which can actually be known is point $G$, representing the present consumption of alternative energy. Point $I$ can be estimated based on the load forecast.

Point $G$ marks the parameters:

\[
Q_A = \text{quantity of alternative energy consumed per month in units of consumed output per month}
\]

\[
P_A = \text{price of alternative energy consumed per unit of consumed output}
\]

Point $I$ marks the parameters:

\[
Q_E = \text{quantity of electricity expected to be consumed in units of consumed output per month}
\]

\[
P_E = \text{price of electricity per unit of consumed output}
\]

An important starting point of the calculation of the socio-economic benefits is the next principle of conventional microeconomic theory (Munasinghe, 1987, pp. 79–82):

The economic benefit (in this article called the socio-economic benefit) derived from consuming a good or service can be measured by the area under the demand curve

The incremental benefit (total shaded area in Figure 2) ($IB$) is the benefit of the energy consumption with implementation of the project minus the benefit without implementation of the project. Related to the areas in Figure 2, this becomes $IB = [OEIJ] - [OAGK] = [AEIKG]$. A more mathematical presentation of the theory can be found in the appendix (Equations (1) and (2)).

The area representing $IB$ can be split in two areas with a different economic interpretation: $IB = [KGLM] + [AEIJML]$. The area $[AEIJML]$ (dark shaded) represents the incremental socioeconomic benefits as a result of the higher quality of electricity supply in comparison with the alternative supply. Similarly, this area can be divided in a part which represents the increased sales revenues as a result of the higher quality (area $[MLIJ]$) and a part which represents the increased consumer surplus as a result of the higher quality (area $[AEIL]$). The area $[KGLM]$ (light shaded) represents the incremental socioeconomic benefits as a result of the lower price of electricity in comparison with the alternative source. This area can also be split up in sales revenues (area $[KHLM]$) and consumer surplus (area $[HGL]$).
The incremental cost ($IC$) of energy supply is the difference between the total marginal cost for electricity minus the total marginal cost for the alternative source (see appendix, Equation (3)). The net benefits of the project can now be expressed as the difference between the incremental benefits and the incremental costs (appendix Equation (4)). The marginal costs for electricity are already included in the project cost analysis, resulting from the supply system design procedure. Therefore, to arrive at the actual project benefits ($B$), the marginal costs for electricity supply have to be excluded from the equation of the net benefits (appendix Equation (5)). The total project costs and the total project benefits will be weighted against each other in the final cost–benefit analysis (see Figure 1).

In addition to the substitution of electricity for alternative forms of energy, the introduction of electricity may also lead to new possibilities of energy consumption. Examples are the use of television and air conditioning, which are hardly possible if electricity is not available. Because these are more luxurious items (especially in developing countries), it first has to be estimated whether these types of consumption are occurring on a scale which warrants paying large attention to them. If one wants to quantify the socioeconomic benefits here, the demand curve for this type of end use has to be drawn. In this case the curve of the alternative source does not exist, so the incremental socioeconomic benefits can be represented by the total area under the demand curve.

The presented theory has to be applied to each type of end use of energy for which electricity is substituted. In applying this theory it may well be possible that the electricity demand curve can not be estimated by the straight line from Figure 2. In these cases estimations have to be made for the electricity demand curve to quantify the socioeconomic benefits. To illustrate this, in the next section two segments of the socioeconomic benefit measurement as used in the Tanzanian case study, will be discussed (Broek, 1993).

### Application of the theory to a case in Tanzania

First, the method of socioeconomic benefit analysis is adapted to Tanzanian circumstances. Thereafter, the selected Tanzanian case will be described, followed by the results and recommendations for improvement.

#### Socioeconomic benefit analysis in Tanzanian circumstances

Two examples of socioeconomic benefits will be discussed. First, we will discuss the socioeconomic benefit which occurs when residential consumers change from kerosene light to electric light and afterwards when cotton ginneries switch from self-generation by diesel generators to grid electricity.

#### Households switching to electric lighting

In the lighting case, both quantity and quality of the consumption of light is expected to increase when one changes from kerosene lighting to electric lighting. Quality increase is mainly formed by increased convenience, more equal light emission throughout the area, less smell and less heat (Plas and Graaff, 1988). By means of Table 1, the commonly used units can be transformed into units which can be conveniently used in the demand graph, namely units of the quantity of light consumed. From this table it can be seen that the efficiency of the electric tube is more than two times as high as that of the bulb. For kerosene the Coleman pressurized lamp appears to be much more efficient than the wick lamp. Further it can be seen that electric lighting in general is much more efficient than kerosene lighting. The kerosene wick lamp stands out of the four lamps mentioned because of its very low output.

The data which set the points $G$ and $I$ (see Figure 2) are based on experiences from the past with respect to the kerosene consumption (Katyea et al, 1993) and on the load forecast, made in the project appraisal of the case which will be presented later (Broek, 1993). It appears that rural households consume on average for lighting purposes 25 kWh per month when they have access to electricity and 8 litres of kerosene per month when they do not have access to electricity.

The larger part of the electric lights in Tanzanian households are electric bulbs and the larger part of kerosene

### Table 1 Lamp output and efficiency of the most common kerosene and electric lamps

<table>
<thead>
<tr>
<th>Type of lamp</th>
<th>Nominal input consumption</th>
<th>Nominal output of luminous flux</th>
<th>Luminous efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incandescent filament lamp</td>
<td>60 W</td>
<td>730 lm</td>
<td>12 lm/W</td>
</tr>
<tr>
<td>60 W (electric bulb)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fluorescent lamp, TL 8 W/29 (electric tube light)</td>
<td>15 W</td>
<td>410 lm</td>
<td>27 lm/W</td>
</tr>
<tr>
<td>Kerosene wick lamp</td>
<td>400 W or 0.041 l/h</td>
<td>40 lm</td>
<td>0.1 lm/W or 0.99 klm h/I</td>
</tr>
<tr>
<td>Coleman pressurized kerosene lamp</td>
<td>500 W or 0.051 l/h</td>
<td>400 lm</td>
<td>0.8 lm/W or 7.9 klm h/I</td>
</tr>
</tbody>
</table>

$W =$ watt; kW = kilowatt; lm = lumen; klm = kilo lumen; l = litre; h = hour

$^a$The most convenient way of expressing the luminous efficiency for kerosene lamps is by using klm h/I, for kerosene consumption is normally measured in litres. To make a comparison possible with electric lamps, the efficiency of the kerosene lamps can also be expressed in lm/W by converting with the help of the energy content of kerosene, namely 35 MJ/l (which equals 9.7 kWh/l).

Source: Plas and Graaff (1988)
lights are wick lamps. To enable mutual comparison, these data are transformed with the help of Table 1 (with the index $K$ filled in for the alternative energy, namely kerosene):

$$Q_E = 25 \left[ \frac{kW \cdot h}{month} \right] \times 12 \left[ \frac{lm}{W} \right] = 300 \left[ \frac{klm \cdot h}{month} \right] \quad (1)$$

$$Q_K = 8 \left[ \frac{l}{month} \right] \times 0.99 \left[ \frac{klm \cdot h}{l} \right] = 7.9 \left[ \frac{klm \cdot h}{month} \right] \quad (2)$$

Financial (market) prices of electricity are US$0.0021/kWh (Broek, 1993)$^{5}$ and the kerosene market price is US$0.28/l (Hosier and Kipondya, 1993). However, the prices which are used in the socioeconomic benefit analysis have to be shadow priced, which gives an electricity price of US$0.051/kWh and US$0.46/l.$^{6}$ Again, with the help of Table 1 these values can be converted to enable mutual comparison:

$$P_{E, ec} = \frac{0.051}{12} \left[ \frac{S}{lm \cdot h} \right] = 0.0043 \left[ \frac{S}{klm \cdot h} \right] \quad (3)$$

$$P_{K, ec} = \frac{0.46}{0.99} \left[ \frac{S}{klm \cdot h} \right] = 0.46 \left[ \frac{S}{klm \cdot h} \right] \quad (4)$$

With these values, we get the demand graph of Figure 3. This figure shows that this is a quite extreme case. The consumer undergoes a change of consuming a very small quantity of very expensive light to consuming a very large quantity of very cheap light. It is quite reasonable to assume here that the increase in consumption is mainly caused by the extremely low price of electric light per klm.h.

Three estimations can now be made to facilitate the assessment of the socioeconomic benefits.

(1a) When people are willing to spend the amount $P_{E} \cdot Q_{E}$ (US$1.29 per month, see Equations (1) and (3)) per month on electric lighting, they are also willing to spend at least the same total monthly amount of money for this purpose, at higher prices (per unit of electric light).

(1b) The kerosene consumption is assumed to be constrained by the maximum amount which people want to spend each month on lighting. This amount thus is $P_{K} \cdot Q_{K}$ (US$3.60 per month, see Equations (2) and (4)). Therefore, it can be expected that the people are not willing to spend more on lighting even if it concerns electric lighting.

The result of this estimation is that (at least), for the demand of light in the range between $Q_{K}$ and $Q_{E}$, an upper and a lower limit can be given for the demand curve for electric lighting (see appendix Equation (6)). Therefore, this leads to a range in which the demand curve for electric lighting is situated. This is illustrated in Figure 4.
(2) Although we do not know the shape of $D_K$ (it is not shown in Figure 4), the difference between the area under the demand curve of electric light ($D_E$) and the area under the demand curve of kerosene light ($D_K$) in the range between $Q = 0$ and $Q = Q_k$ is very small in comparison with the total area under the demand curve for electric light in the range between $Q = Q_k$ and $Q = Q_E$ (see appendix Equations (7) and (8)). Therefore it will be neglected. If this is related to Figure 2, we could say that the area $[AEGF]$ is very small in comparison with the area $[KFLI]$. On the one hand this is caused by the fact that $Q_k$ (representing $Q_d$ of Figure 2) is very small in comparison with $Q_E$ and on the other hand by the relatively small difference in quality of light (at equal quantity levels).

(3) The marginal economic supply costs of kerosene are equal to the economic (shadow priced) price of kerosene (appendix Equation (9)). This economic price can be seen as the average economic supply costs.

By including these three estimations into the equation that describes the project benefits (appendix Equation (5)), we can estimate a maximum and minimum value of the socioeconomic project benefits ($B'_{max}$ and $B'_{min}$) for residential lighting in Tanzania. The total quantified socioeconomic project benefit related to electric light consumption for a Tanzanian household is therefore believed to be in the range of US$8.28-16.6 per month (see appendix Equations (10) and (11)).

**Diesel generator owners switching to grid electricity**

The second illustration is the switch of cotton ginneries from diesel based self-generation to grid electricity. From information of the side of the ginneries and from reliability data of the Tanzanian electricity supply, it was concluded that the supply quality increase was not significant. The main reason for this is that the present diesel turbines were relatively reliable. Therefore, the bottleneck in logistics was not the power supply, but the availability of spare parts for the production system. Furthermore, it was clear that in this case the demand elasticity for energy prices was negligible, within the limits of the cost of the diesel generation and the grid electricity. Energy demand was determined by other factors, like availability of cotton and spare parts. Therefore, the additional area under the demand curve could best be estimated as zero. This only leaves the (shadow priced) saved costs of diesel consumption ($MC_{diesel} * Q_{diesel}$) as the socioeconomic benefit for the ginneries. These data could relatively easily be obtained at the ginneries themselves.

Here we see that for this purpose the results of the socioeconomic benefit analysis are equal to those of the economic benefit analysis, because there is no increase in welfare above the increase in national income.

However, if the power supply before the electrification project would have been a logistical bottleneck and if the reliability of power supply after the electrification project was significantly increased, this could have resulted in lower production costs and/or a higher turnover. In that case, there would have been additional economic benefits, in the form of a higher value added of the production process in the ginneries.

To illustrate the constructive task of a rural electrification project appraisal, the next three sections describe the application of the method to the Tanzanian case.

**Case description**

The project under consideration in this section is the agro-based rural electrification project in Shinyanga region in Tanzania (Broek, 1993). The main consumers were four cotton ginneries, an oil mill, a water supply plant and three townships. The townships all together only accounted for 22% of the total forecasted electric energy consumption. The forecasted total maximum (active) power demand was 2 MW and the forecasted annual energy consumption 10 GWh.

For the purpose of this study, the project was evaluated ex post. The project had already been implemented at the time of evaluation. With respect to the least supply cost option, we therefore limited ourselves to the option of a central grid, that had also been chosen in practice. The optimization, however, led to different dimensions as the ones actually used. The grid was connected to the substation near Shinyanga, with a sub-transmission voltage of 33 kV. In total almost 200 kilometres of 33 kV line was needed.

Normally, at ex ante evaluations of rural electrification projects in such areas with low population densities, much more attention should be paid to decentral power supply options eg improved diesel sets, small scale power generation from gasification of biomass residues, or solar home systems.

**Results**

The socioeconomic benefits are calculated as described above, including the saved costs for batteries.

In the calculation of the economic benefits for households the saved kerosene costs are also increased with the saved costs ($MC_{diesel} * Q_{diesel}$) of batteries (seven batteries per consumer per month with US$0.39 as economic costs per battery). For the industrial consumers the economic and socioeconomic calculation were equal, as described above. As project lifetime a period of 12 years is used, including 2 years for construction. The discount rate used is 12%.

In total amounts the discounted costs and benefits were:

- **Financial costs**: US$5.8 million
- **Financial benefits**: US$3.8 million
- **(Socio)economic costs**: US$6.0 million
- **Economic benefits**: US$3.9 million
- **Socioeconomic benefits**: US$4.1 to US$4.4 million

As indicated in the beginning of this article, the estimated non-quantifiable benefits are relatively limited. A non-quantifiable benefit which basically should be added is the fact that those people who change towards electricity also change towards sustainable energy supply in the form of...
hydro power. This may lead to reduced environmental external costs.

The resulting cost–benefit parameters were:

- **Financial NPV**: US$–2.0 million
- **Economic NPV**: US$–2.1 million
- **Socioeconomic NPV**: US$–1.9 to US$–1.6 million
- **Financial BCR**: 0.66
- **Economic BCR**: 0.65
- **Socioeconomic BCR**: 0.74 to 0.68

Main results from the sensitivity analysis were:

1. If the initial investment costs would have been reduced with 50%, the NPV's would still remain considerably negative;
2. To make the project financially viable, the electricity tariffs should be raised (in constant US$ terms) with 53% on average;
3. A rise of at least 40% of the (shadow priced) fuel prices would be necessary to make the project economically viable;
4. The range in socioeconomic benefits for residential lighting has limited influence because of the limited share of household consumption in the total project consumption; and
5. When TANESCO would only undertake the most financially viable part of the project (which gets a positive NPV at ginny electricity tariff increases of 47%), the government could decide to support the electrification of the townships. When the 33 kV line is available, the electrification of these townships showed an almost positive (socio)economic NPV. To make the distribution of electricity to the townships also financially viable, the electricity tariffs of the township consumers on average have to be raised by 77%.

Therefore, it can be seen that we are confronted with quite poor results of the project. The main underlying reasons for this will be more clear in the constructive part of the appraisal.

To get insight in the main problems and find solutions for them, two main bottlenecks were selected for discussion in this section:

1. Ineffective electricity tariff system, which resulted in insufficient tariff revenues earned by TANESCO; relatively low economical benefits because of low connection rates; and less non-quantifiable benefits than expected.
2. Low power factors.

**Possible means for improvement**

The electricity tariff system Some measures which will lead to improvements in the performance of rural electrification projects are to: raise electricity tariffs to long-run marginal supply costs; adjust lifeline blocks; and spread connection charges over more years.

If the tariffs are not raised to the long-run marginal supply costs of electricity, there will be no incentive at all for TANESCO to undertake rural electrification. It can be expected that especially for those people who are already supplied by cheap electricity, tariff increases may raise a lot of protest. However, if rural electrification in Tanzania should have any perspectives, price increases are likely to be unavoidable. Such a conflict in the power supply policy between economic efficiency and affordability is present in many developing countries.

A good compromise can be found in a suitable system of lifeline tariffs. This is a tariff system which allows people to obtain a portion of cheap electricity to meet their basic demands. Demands above this level are much more expensive in lifeline tariff systems.

Officially the approach of lifeline tariffs is already used at the moment in Tanzania. However, as has been indicated by Hosier (1993), the way in which it is implemented is very ineffective. With the present system residential consumption up to 1000 kWh per month is heavily subsidized. This would allow for extensive electric lighting, cooking and refrigerating. A more rational lifetime tariff could lead to much more conscious use of electricity and more tariff revenues for TANESCO. TANESCO, in cooperation with the government, has to make a choice what kind of activities have to be subsidized by means of a lifetime tariff. Lifeline tariffs should be consciously directed on these choices. When the subsidy is meant for lighting purposes only, a lifeline block of 25 kWh per month will be sufficient (Foley, 1992). When a subsidy for cooking is also considered suitable (for instance to reduce deforestation), a lifetime block of about 150 kWh per month will be sufficient. Above these lifetime blocks the consumers should have to pay the long-run marginal costs for electricity supply or even a bit more to compensate for the lifetime subsidies.

Further, as can be seen from Figure 3 and as has been indicated by Kjellström et al. (1992), in the present situation the money spent by non-electricity consumers is much higher than that of the subsidized electricity consumers. If subsidies, like in the lighting case discussed above, lead to a total amount spent on electricity for a certain purpose which is much lower compared with the alternative energy source, the subsidy can be considered as too high. One should keep in mind that the original aim generally is just to make electricity available. Lifeline subsidies should not be directed at considerable cost savings of the residential consumers at the expense of other (for instance industrial) consumers.

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7The average residential (mainly urban) consumption in Tanzania (consumed by those who can allow the connection charges) is about 350 kWh per month and will be considerably lower in rural areas. Data from the research of Kjellström et al. (1992) showed average energy consumption of residential consumers of about 150 kWh per month. Looking at these figures it will be clear that the size of the two very cheap lifeline blocks of 1000 kWh per month does not make any sense.
8Households in rural areas which were able to afford an electricity connection end up with costs for cooking which were in a range of 4–15 times as high compared with cooking on electricity (Kjellström et al., 1992).
Another way of making electricity available to more people can be found in the structure of the connection charges.

At this moment the electricity consumers have to pay connection charges at the moment of taking a connection. For many people in rural areas in Tanzania this appeared to be one of the main reasons for not taking a connection at all (Kjellström et al., 1992). Paying a relatively large amount of money (about three times as large as the monthly minimum wage) at one time is an insurmountable barrier to get an electricity connection for many Tanzanian people who are hardly able to meet their basic daily needs and therefore can not save money. Saving money is even more discouraged by poor banking facilities and high inflation rates.

Together with the low percentage of people that can actually be expected to cook on electricity, these connection charges are the main reason that the large non-quantifiable benefits, as mentioned in the rural electrification policy (like avoiding deforestation and improving the situation of women) could not be expected to occur (Kjellström et al., 1992). Because of the high connection rates, even some negative non-quantifiable 'benefits' can be found in the form of less equal income distribution because of the fact that only those people who can afford the connection charges are able to profit from the (cross-)subsidized electricity.

To solve this problem two approaches could be used. The first approach is to treat the connection costs made by TANESCO in the same way as the other capital costs, thus to recover them by slightly higher kWh-tariffs. The second approach is to spread these connection costs over a number of years (so that the discounted present value remains the same) in the form of a fixed amount which has to be paid each month by the consumers. These approaches will be especially useful for the residential consumers.

This problem is quite general in developing countries and many authors have already pointed at it (Broek, 1993; Foley, 1992; Kjellström et al., 1992; Munasinghe, 1981; Munasinghe, 1990). However, up to now this remains one of the main bottlenecks in the electrification of Tanzania.

It should be stated that the tariff measures cannot be implemented separately from each other. When the possibilities for households to obtain a connection become higher because of spread payments of connection charges, drastic modifications as described under the first two points become even more essential. On the other hand, when tariffs are increased without adapted connection charges and suitable lifeline tariffs, this may lead to a lower load growth, which may have an even more negative effect on electrification projects.

Beside these three measures, some additional measures could be undertaken to solve the 'tariff system' related problems.

People should be enabled to wire their houses cheaply. Beside the high connection charges, the people who want to take a connection also have to pay high amounts for their house wiring. The government (in cooperation with TANESCO) should set standards for house wiring which is safe but as cheap as possible. Experiences in other countries learned that appropriate technology for house wiring which may deviate from Western standards can function well and save lots of money (Holland, 1989; Mackay, 1990). Credit facilities to pay for these initial investments would enable more people to take a connection once their village is electrified.

If the Tanzanian government is serious about avoiding deforestation by means of rural electrification, it is absolutely necessary that people are enabled to buy electric cookers. This could be in the form of credit facilities or regulations which enable spread payments. Without these measures people will in many cases not be able to cook on electricity and rural electrification will hardly have any influence on deforestation.

When calculations (using discounting techniques) show that shifting to electricity for lighting or cooking saves money for the consumer, this does not automatically mean that those people, who have to make the decision whether to take a connection or not, realize these financial consequences. It is very difficult for many consumers to make a rational comparison between options with different variable and fixed costs. Therefore, supply of information to consumers is essential.

Another additional measure which could be taken to stimulate the use of electricity for cooking purposes is to demonstrate to the villagers the way traditional cooking practices can be adapted for convenient cooking with electric cookers (Mackay, 1990).10

Low power factors The power factors at the cotton ginneries (which were previously supplied by own diesel generation) were very low, namely just above 0.6. This was mainly caused by the large number of small electric motors and the under-utilization of many motors. In the project appraisal it has been assumed that the ginneries will invest in capacitor installations to improve this power factor. This appeared to be a very cost-effective measure (Broek, 1993). However, in practice these investments have not yet been made. Because of the fact that there is quite little experience in Tanzania with power factor correction, future electrification programmes could benefit a lot from attention paid to this subject. Research should be initiated by the government or TANESCO, probably in cooperation with experienced consultants, to make an inventory of the possibilities and the consequences of power factor correction at company level. Guidebooks could be made to enable other firms to measure and, if desired, to correct their power fac-

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9In a field study undertaken by SEI and TANESCO it appeared that 50% of the people who had no electricity connection in an electrified area, blamed this on the fact that they were not able to pay for the connection charges (Kjellström et al., 1992).

10In the case of Nepal motivators demonstrated the new cooking practices. When cookers were broken, the motivators take care of the repair and return them to the consumers and explain again how to use it properly (Mackay, 1990).
When many factories in Tanzania have power factors like the studied cotton ginneries, a national programme with respect to power factor improvement on company level could be very cost-effective for both TANESCO and the consumers under consideration.

Conclusions

Project appraisal can be undertaken both from the point of view of the electric utility, which is called the financial analysis, and from the point of view of the national economy, which can either be a economic or socioeconomic analysis. In all types of appraisal, the most important steps which have to be taken are the power market survey, load forecasting, supply system design including cost calculation, benefit measurement, the cost–benefit analysis and the sensitivity analysis. Of these steps the socioeconomic benefit measurement gives the most theoretical problems. Partly, the socioeconomic benefits can be calculated by the values of the previous energy consumption and the expected electricity consumption. For the estimation of the socioeconomic benefits representing the consumer surplus the shape of the demand curves has to be known or has to be estimated. This shape will be different for each type of end use of energy.

Beside just using the project appraisal for a 'go' or 'no-go' decision, it is possible to give it a constructive function. With help of the knowledge which is gained during the appraisal process (especially in the sensitivity analysis) the main bottlenecks of the project can be identified. This can be completed by looking for ways to eliminate the bottlenecks, which will result in a more viable project and in better performances of future projects.

In the Tanzanian case which was studied, the main bottlenecks were rooted in the tariff system. Tariffs should be raised to long-run marginal cost levels to enable TANESCO to pay for their costs. This should be accompanied by more rational lifeline tariffs. If lifeline tariffs have to enable electric lighting the present lifeline block of 1000 kWh per month could be reduced to 25 kWh per month. The major discouragement for consumers in taking an electricity connection were the high connection charges. If rural electrification in Tanzania is meant to play a role in avoiding deforestation, new electricity consumers should also be enabled to pay for electric cookers, probably by means of spread payments. Consumers should be enabled to spread their payments for these charges. Another bottleneck was the situation of bad power factors of the cotton ginneries. Corrective measures appeared to be very cost-effective. This signal of bad power factors justifies further research in this subject with other industrial consumers.

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References

Appendix

The two demand curves of Figure 2 can be presented as the energy price as a function of the consumed quantity:

\[ D_E \rightarrow P_E = f_E(Q) \]
\[ D_A \rightarrow P_A = f_A(Q) \]  

(1)

The incremental benefits can now be written as the difference between two integrals, representing the surfaces \([OEIJ]\) and \([OaGK]\).

\[ IB = \int_{Q=0}^{Q=Q_E} f_E(Q)dQ - \int_{Q=0}^{Q=Q_A} f_A(Q)dQ \]  

(2)

The incremental costs can be written as:

\[ IC = MC E \ast Q_E - MC A \ast Q_A \]  

(3)

With:

\[ MC E \ast Q_E : \text{total (economic) marginal supply costs of electricity} \]
\[ MC A \ast Q_A : \text{total (economic) marginal supply costs of the alternative energy source} \]

This results in the net benefit \(NB\) of the project:

\[ NB = IB - IC = \int_{Q=0}^{Q=Q_E} f_E(Q)dQ - \int_{Q=0}^{Q=Q_A} f_A(Q)dQ - MC E \ast Q_E - MC A \ast Q_A \]  

(4)

The term \(MC E \ast Q_E\) is usually referred to as the total project costs \((C)\). These are the costs that result from the supply system design procedure. Therefore to arrive at these total project benefits \((B)\), the total project costs have to be excluded from the equation of the net benefits. The project benefits \((B)\) can now be written as:

\[ B = \int_{Q=0}^{Q=Q_E} f_E(Q)dQ - \int_{Q=0}^{Q=Q_A} f_A(Q)dQ + MC A \ast Q_A \]  

(5)

The incremental costs can be written as:

\[ IC = MC E \ast Q_E - MC A \ast Q_A \]  

(3)

The third estimation can be expressed as:

\[ MC K = P_{K,ec} \]  

(9)

With the help of these three estimations we can fill in Equation (5) and thus calculate a lower and higher estimation of the socio-economic benefits of residential light consumption per month:

\[ B_{\text{run}} = P_{E,ec}Q_E \int_{Q=0}^{Q=300} \frac{1}{Q} dQ + P_{K,ec}Q_K \]
\[ = 3.60 \int_{Q=8}^{Q=300} \frac{1}{Q} dQ + 3.60 \]
\[ = 3.60 \cdot \ln \frac{300}{8} + 3.60 \]
\[ = 13.0 + 3.60 = 16.6 \]  

(10)

Note that the suffices again refer to the alternative energy option of kerosene. The second estimation now becomes:

\[ B = \int_{Q=0}^{Q=Q_E} f_E(Q)dQ - \int_{Q=0}^{Q=Q_A} f_A(Q)dQ + MC A \ast Q_A \]  

(6)

For the second estimation it is necessary first to rewrite Equation (5) into:

\[ B = \int_{Q=0}^{Q=Q_E} f_E(Q)dQ - \int_{Q=0}^{Q=Q_A} f_A(Q)dQ + MC A \ast Q_A \]  

(7)

The mathematical presentation of the three estimations made in the assessment of the socioeconomic benefits is as follows:

Estimation 1: for \(Q_k < Q < Q_E\):

\[ \frac{P_E \ast Q_E}{Q} \leq f_E(Q) \leq \frac{P_K \ast Q_K}{Q} \]  

(6)

The third estimation can be expressed as:

\[ MC K = P_{K,ec} \]  

(9)