Energy planning

Criteria to support project identification in the context of integrated grid and off-grid electrification planning

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March 1998
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EXECUTIVE SUMMARY

The focus of this paper is on the operational level processes of project selection and prioritisation, and appropriate choice of technology (grid or off-grid) for rural electrification. The paper is part of a suite of four documents that look at different aspects of decision-making criteria for grid and off-grid electrification planning. A parallel paper written by Cecile Thom discusses strategic level criteria; Paul Galen of NREL has undertaken an international review, and Hilton Trollip is preparing a document which looks at the role and possibilities of Geographical Information Systems and databases in electrification decision-making.

Objectives, and research methodology

The research objectives were to review existing criteria used in rural electrification decision making, and to present for discussion a set of criteria to assist electrification at the operational level.

The research reviewed existing published material, and documentation on electrification planning and decision-making provided by key organisations. Two consultative workshops were held, and a number of more detailed discussions with key players took place. Economic and financial analyses of different electrification options and of electrification under a range of different settlement conditions were not carried out as part of the study, although available case study evaluation work was reviewed.

Overview of rural electrification

A review of electrification activity in South Africa indicates that the grid programme is strongly dominant, with current activity taking place on a sustained and massive scale (450 000 connections annually, of which the majority are in rural or peri-urban areas). In areas remote from the grid, there has been some private sector Solar Home System activity, but little community-wide publicly supported activity for off-grid household electrification (the community of Maphephethe in KwaZulu-Natal, and a project for farmworkers in the Free-State being the principal active projects to date). A number of Solar Home Systems projects are in an advanced stage of planning. Institutional use of solar systems has been implemented on a larger scale, with the Eskom schools project and the IDT clinic project being the major activities. There have been a limited number of mini-grid projects in South Africa, with either diesel or micro-hydro being the principal power source. Battery-charging stations are running in a number of areas (some using PV as the generation source).

Principal constraints to large-scale off-grid electrification activity are listed below.

1. There is uncertainty regarding future grid electrification plans, communities and off-grid service providers often having insufficient information on grid options to make good decisions about off-grid investments.
2. Rural communities express a strong demand for, and have a high expectation of getting, grid electrification.
3. There are difficulties in establishing appropriate financing for off-grid systems.
4. There are delays in achieving roll-out of an agreed subsidy from the fiscus for pilot-scale off-grid electrification projects.

The first two of these constraints highlight the need both for criteria and for public, transparent long-term grid electrification planning.

Costs and benefits of electrification options

Grid capital costs per connection are primarily affected by the length of line extension required (and any bulk supply upgrading that may be required), proximity of households to each other, settlement size, topography, and the design After Diversity Maximum Demand. Revenues are strongly dependent on actual user consumption and, in some cases, non-technical losses (theft). Service costs are significant – of the order of R21 per month per household. Both operational and

capital costs can be significantly reduced (by approximately 30%) if a limited-current supply option is utilised – 2.5 A, or possibly 8 A – rather than the more usual 20 A prepayment meter option.

Off-grid household electrification costs, on the other hand, are not very sensitive to location of settlement with respect to the grid, proximity of households to each other (except for mini-grid), settlement size and topography. There is a significant capital cost sensitivity to design daily load, but little subsequent revenue link to actual consumption. Maintenance costs are significant, with replacement of batteries being required approximately every three years at a cost of R300. Estimates of service costs vary from zero (no back-up provided), to R16 (field experience is urgently required).

The costs and benefits of different electrification options from the user perspective are in part quantifiable, but in part more qualitative. For those that get a connection to the grid:

- Grid is cheaper for the user (connection fees in the range R50 to R140 and an energy tariff of 28 c/kWh).
- A 20 A grid supply has the potential to be used for thermal needs.
- Grid offers greater potential for income generating activities.
- Off-grid options tend to have a far higher cost *to the customer* (of the order of R40 to R120 per customer over a four-year financing period; cost can be less if user pays a tariff for service, as in a utility model).
- While off-grid options provide the same services that most householders actually gain from the grid (lighting and powering of TV and radio/hi-fi), the service is limited, and does not offer the potential to be used for cooking, heating water, space heating or refrigeration, which needs can be more effectively met through other energy supply initiatives).

Both grid and off-grid can help to improve the lighting and communication facilities at clinics, schools and other public facilities. Vaccine refrigeration can be effectively powered using photovoltaic powered systems. In both schools and clinics, grid electrification does, however, provide greater opportunities for supplementary improvements than most off-grid systems. In particular, cooking can be much easier. Water pumping, although possible and often economically viable using off-grid renewable resources or diesel pumping, is usually much easier to carry out, as well as cheaper, if the grid is available.

Thus, in summary, grid connection of a community offers significant advantages, and is the clearly preferred option, if it can be attained. Consequently, when comparing grid and off-grid options for a particular community, one is not comparing like with like. It is necessary, when making a selection, to include both direct financial costs and benefits in the analysis, as well as an understanding of the broader quantitative and qualitative differences.

Electrification planning framework

Operational-level planning is assumed to take place within a larger electrification resource allocation framework. The principal stages are:

- A national level identification of programme priorities and objectives, with definition of a multiyear programme budget.
- Allocation of resources to regions, with regional fairness in resource allocation, economic potential, and the need (demand) for electrification in these regions being the primary criteria. (See Thom (1998) for further discussion of this level of resource allocation).
- Allocation of resources to sub-regional planning areas, using similar criteria to those for the regional allocation.
- Sub-regional project identification and technology selection.

Two additional strategic questions were identified:

- A separate budget could be allocated at the National level for MV and HV transmission and bulk infrastructure development.
- There could be an explicit national level allocation to off-grid electrification.

At the sub-regional (operational) level the key questions are:

- Which settlements in a region should be electrified using the grid?
- Which settlements in a region should be electrified using off-grid technology?
- How should electrification projects be prioritised relative to each other?
- What conditions should either grid or off-grid projects satisfy before actual project implementation can be approved?

Criteria currently being used in electrification decision making

Current electrification planning is focused on grid rollout, with a primary emphasis being on the identification of projects in the short term (one to two year planning horizon). Longer-term plans are more general, and subject to change. There is generally little integration between grid and off-grid planning, although efforts are being made to change this. As a result, off-grid planning is sometimes invalidated by the unexpected arrival of the grid.

Minimisation of capital costs per connection is the main selection criterion within the Eskom-dominated rural electrification programme. This is primarily a result of the target-driven nature of the programme, coupled with an appreciation that the programme is not financially viable. Revenues generally do not cover the operating expenses, let alone the capital investment. Capital costs represent the largest portion of the 20 year NPV of projects, given the generally low consumption rates. Thus the principle way to minimise losses is to minimise the initial investment. Capital cost criteria (maximum allowable cost per connection) used by Eskom do vary from region to region, in acknowledgement of the differing conditions in different parts of the country.

Both Eskom and the DBSA utilise a shared spreadsheet-based financial and economic cost/benefit analysis model. Subject to certain qualifications regarding the reliability and appropriateness of consumption and loss of revenue data used, the tool does provide a potentially very useful indication of project financial viability from the utility perspective, and of the potential economic costs and benefits to society as a whole. The results of the analysis are primarily used by Eskom for project acceptance/rejection decisions, rather than being used as one of the inputs to prioritisation.

Central to the financial analysis of grid electrification projects is an estimate of the electricity consumption growth rate in communities. Consumption plays an even bigger role in an economic analysis, as a 'willingness to pay' component comprises part of the benefits. Formal socio-economic surveys are not currently undertaken by Eskom prior to electrification decision-making. Thus the data used in analyses to support decision making is usually based on average data (often for the region), modified by windshield-type assessments of settlement conditions. This does not adequately distinguish between different settlements or between different groups of people within settlements.

Technical design criteria and guidelines for grid reticulation network on Eskom projects are not explored in detail here. There is, however, a move towards installation of lower capacity reticulation systems, transformers and bulk supply (design ADMD of 0.4 to 0.7 kVA). This is motivated by capital resource constraints, and in line with a downward revision of expected consumption growth curves, and possible greater use of the limited-current supply options. The implications of such changes on future network extension and network upgrading budget requirements have not been assessed here. A national policy on the capacity of supply adequate for rural electrification has not yet been clearly articulated.

Off-grid technical design criteria are even less clearly articulated, although there is a general acceptance of the need to provide energy for household lighting, and radios and/or monochrome television. In principle, the importance of technical quality assurance for off-grid components and systems is acknowledged, although the mechanisms for assuring this are not yet in place.

Community facilities (schools and clinics) are considered in household electrification project CBA evaluation. Furthermore, there are dedicated programmes to supply electricity to community facilities. However, the general thrust of the main electrification programme is a drive to meet domestic supply point connection targets, and community facilities are not accorded the weight that they should be in general electrification planning.

Integrated planning and the need for better communication between different sectors involved in rural development are widely acknowledged within the institutions as being important, but are, however, difficult to achieve. Reasons given include: grid electrification planning being frequently in advance of other development planning; disparate allocation of responsibility for different functions; delays in the establishment of planning forums; lack of definite information; and a tendency for communities to focus on one service at a time in seeking to meet their needs.

Public involvement in electrification planning has taken place at various levels, with mixed success. While forums have facilitated prioritisation in some regions, in others strongly articulated inter-settlement equity concerns have resulted in small, partial settlement electrification options. Taking as a given the general high demand for grid electrification, Eskom has tended to avoid significant interaction with communities prior to a decision being made in this regard. This highlights a tension between a knowledge that communities should be directly involved in decisions, and at the same time sensitivity to the significant implications of a decision not to electrify. This tension has been exacerbated by the lack of a real, worked out alternative to grid. The off-grid delivery and financing infrastructure is simply not in place.

Information and analysis to support decision making

The availability of data to support electrification decision making is improving rapidly. For most rural areas information is available on:

- settlement size (number of households);
- settlement area (which together with the above can be used to estimate the number of connections per km^2);
- settlement shape;
- location of schools and clinics;
- status of electrification in the area;
- some indication of water supply status;
- road infrastructure.

Although settlement specific demographic data is not as readily available, by mid 1998 it should be possible to link census data to 'enumerator areas', which will also give some indication of income and wealth in settlements. Information regarding informal and formal business activity in communities is generally not available. Furthermore, although a number of energy consumption surveys have been carried out, sub-regional variations can be significant.

Information requirements

Information requirements for electrification planning can be divided into the following areas:

- capital costs of particular options;
- lifecycle financial costs and expected revenues;
- lifecycle economic analysis (costs and benefits);
- consumption growth potential, and indicators thereof, as well as some indication of the load profile;

- community empowerment and involvement opportunities;
- settlement status;
- availability and status of public facilities and amenities (water, roads, health facilities, schools);
- potential for economic development and non-domestic demand;
- other energy issues in the area;
- development planing and development initiatives.

While the majority of the information feeds into the financial and economic analysis, some of the issues require a separate or more qualitative analysis.

If rational prioritisation of settlements for electrification is to take place, then it is important to identify key parameters that will differ significantly from community to community. The obvious one is capital cost, and this certainly requires the most attention. Also significant for grid projects, however, is the consumption rate, as significant differences in consumption levels have been noted between communities – Davis (1995) reports settlement average consumption per connection ranging from less than 20 kWh/month up to 150 kWh/month 30 months after electrification. The most commonly used indicators of potential consumption are income or wealth related measures, but there is some concern regarding the accuracy of income information, and the validity of the link between pre electrification income and future expenditure on electricity. This is an important area for further research.

Financial and economic analyses

Financial and economic[1] analyses can be used in a number of different ways to assist electrification decisions. It is important to establish the depth of analysis required, and the perspective of the decision maker using the analysis. From a review of analyses carried out for different electrification options, the following main points are noted.

1. From the customer perspective, grid electrification using a prepayment meter, at current connection and tariff rates is financially and economically preferable.
2. Grid electrification projects are generally not financially viable at current tariff and consumption levels (with life cycle NPV per connection of the order of negative R3500).
3. From a national perspective, economic analyses of rural grid electrification projects yield mixed results. A review of thirty projects in 1995 indicated that 60% of projects had a negative economic NPV, with an approximate normal distribution of the economic NPVs around zero (Matlhare & Steyn 1995). Davis (1997), using a similar model, but accounting more fully for the benefits, reported a positive NPV for the remote community of Mafefe. Solar electrification did not yield a positive economic return in the analysis carried out by Davis.
4. Off-grid systems are likely to have a low penetration rate at cost-reflective tariffs (as the user costs would be high for the service delivered). Reducing tariffs to levels more comparable with those of the grid (for the user) will mean that off-grid projects are also not generally financially viable without some measure of subsidy or very soft loan.
5. Off-grid options tend to be financially more attractive **relative to the grid,** where grid capital costs are high (remote, small settlements, low household density), and/or consumption rates low.
6. However, from an economic perspective, prepayment metered grid supplies are optimal over greater consumption and capital cost ranges.

[1] In this report, the term 'economic analysis' is used to describe a modified and extended financial analysis, which explicitly considers the national view. See section 4.3.1.

As will be discussed later, financial and economic analyses are seen as essential to both project prioritisation, and technology selection.

Other factors to be included in electrification decision making

Economic and financial analyses do not capture all aspects relevant to electrification decisions. Certain issues are best dealt with as specific explicit criteria (for example, projects should not cause undue damage to environmentally sensitive areas). Others, such as the social developmental benefits attributed to electrification of community facilities can be dealt with through an index approach, with points being allocated on a score system for different electrification activities. Alternatively, they can be incorporated in economic analyses using explicitly defined (standard) cost and benefit parameters. Lastly, their relevance to decision processes can be qualitatively reported to decision-making bodies, and incorporated in an explicit, but not necessarily quantified, manner.

A 'best practice' set of criteria for operational planning

In an attempt to draw the work together, and present a basis for further discussion and development of criteria, a best practice set of criteria have been developed, and described within a decision-making approach. Key principles used in developing this approach are identified below.

Electrification policy

Electrification is seen as a worthwhile endeavour, which aims to provide at least a minimum level of services to permanent households and communities in a sustainable manner, using resources in an economically efficient manner.

- By 'minimum level of service' is meant that households should be able to use electric lights for a few hours in the evening, and operate low-power entertainment and communications devices. Community facilities such as clinics, and schools should have access to the minimum electrical energy required for daily operation and communication.
- By 'sustainable' is meant that reasonable assurance can be provided of long term continued availability of the service, supported by revenues, and where necessary through defined and assured alternative resources (typically cross-subsidies).

Electrification activities should seek to maximise the benefits achievable, through supply of a higher level of service than the minimum level noted above, where this can be economically justified and where the extra financial cost (if any) can be managed and will not jeopardise the electrification programme or the industry.

The social and economic benefits of both the electrification process and the subsequent service delivery should be maximised through appropriate project design and management, involvement of community members, and through active identification and development of economically viable opportunities.

Situations where provision of electricity will facilitate broader economic development should be actively identified and developed.

Planning context and principles

Within the resource allocation process described above, operational level planning is assumed to take place:

- in regions small enough that political questions of geographically equitable resource allocation are not relevant (these should be dealt with at the strategic level)
- within a reasonably defined resource base (thus planners have an idea of the magnitude of resources available)
- primarily within a programmatic fashion, although provision is made for project specific decisions
- in a series of iterations, with decisions being gradually firmed up as further information is gathered, and the necessary consultation takes place

- in a flexible manner, with evaluation of projects and adjustment of planning criteria taking place on an ongoing basis, and with a sensitivity towards differing levels of data availability
- in a manner such that long-term grid planning is prioritised and publicised, to allow both communities and service providers to make informed decisions about off-grid investments
- in a multifaceted funding environment, but with decisions strongly influenced by the national best interests.

This is consistent with (but not necessarily dependent on) the possible establishment of a National Electrification Fund.

Criteria for first level decision-making

Decision making will take place in a number of stages. The first is to allocate settlements to one of three categories:

- those where **grid** electrification is definitely the preferred option;
- those where **off-grid** technologies are readily identified as being more appropriate (remote, small communities);
- and an **uncertain** area for which decisions are not as readily made.

Categorisation into these three areas can be achieved relatively quickly using available data such as settlement size, proximity of households to each other (density), distance between settlements (or if closer to the nearest grid line), coupled with the considerable grid electrification design and costing expertise already gained in South Africa. Where income-related data is available this can be incorporated as an indicator of potential consumption. GIS systems are expected to play a major role in this first pass categorisation process. Additional factors, such as knowledge of related development plans in other sectors, and information on particular site specific opportunities for economic benefit, should be used to modify the preliminary ranking.

Narrowing the 'uncertain band': two approaches and associated criteria

The 'uncertain area' presents the greatest difficulties, and has been the focus of most attention. From the off-grid point of view, these areas are likely to include the most economically viable projects as settlements tend to be larger, less poor, and closer to existing infrastructure than those in the easily identified 'off-grid' area. Two approaches to reducing the number of settlements allocated to the 'uncertain' category have been identified, the 'grid prioritised' and the 'rational technology' approach.

The '**grid prioritised**' approach:

- assumes that grid connection is the strongly preferred option for a variety of reasons (not all readily quantified);
- accepts that economic, financial and social benefits analysis is adequate to prioritise projects which deliver comparable benefits (at least in the first instance); and
- acknowledges that economic analysis is a relatively blunt instrument to rank options that deliver significantly different benefits (that is, that 20 A grid vs. off-grid decisions cannot easily be made on the basis of techno-economic analysis, particularly in borderline cases).

As a result, off-grid areas are defined primarily a result of carefully prioritised long term grid planning, carried out in the context of a defined financial and institutional grid electrification resource.

The '**rational technology**' selection approach assumes that in the more 'uncertain area' cases, a careful technology choice is made, rather than allowing the grid/off-grid decisions to be essentially a by product of a grid planning exercise. This approach requires an accurate social, technical and economic evaluation of grid / off-grid costs and benefits which has a sufficient level of confidence to allow robust grid/off-grid decisions. In order to improve decision making accuracy, it is recommended that thermal needs (and energy supply options to meet these needs) be included in the evaluation.

Both approaches rely on financial and economic analysis of projects as the principal decision-making tools (either for prioritisation or technology selection). However, in the 'grid prioritised' approach, since one is primarily comparing like with like, there is less need for absolute rather than relative assessment techniques. The 'rational technology' approach requires good attention to allocation of the costs of grid infrastructure development, and to assessment of specific load requirements (particularly of potential productive activities), as these can significantly affect the costs and choice of optimum design for off-grid options.

For both approaches, due attention should be paid to:

- business, productive enterprise and social service electricity requirements (clinics, schools, water supply);
- identifying specific opportunities for extra benefits; and
- an assessment of expected consumption growth on a settlement specific basis.

While the requirement that financial and economic analysis of electrification projects using settlement specific data be carried out as a project selection process may seem onerous:

- software tools are already in existence for grid CBA analysis, and could be adapted to facilitate off-grid project evaluation;
- in many cases decisions can be made without requiring detailed analysis if the option is clearly grid, or clearly off-grid;
- typical project investments are significant, and wise decisions are imperative;
- mistakes are expensive: socially, politically and economically;
- unless settlement specific data on business activity, community facilities, wealth and willingness to pay are determined, electrification planning will continue to be driven by least-capital-cost considerations.

The choice of whether to place primary emphasis on the economic or the financial analysis results derived above (for either approach) will depend primarily on the policy and perspective of decision-makers. If the objective is to utilise the available resources to achieve as wide a coverage as possible, then the financial analysis will be more important. If, on the other hand, maximisation of the national economic benefit is the main concern, the EIRR (or economic NPV) will carry a greater weight. Both results are important and decision-makers should consider these and other considerations as discussed below.

Adjustments to priorities for grid electrification (grid prioritised approach) should be made on the basis of the following:

1. Settlements which are of significant importance (relative to others) in the region, should be moved up the priority list. These can be identified through the following indicators:
   - settlement size
   - presence of schools, health facilities, and public administration offices
   - location with respect to important transportation routes
2. Settlements that are likely to contribute to, or benefit from, planned regional development initiatives should move up the priority list for electrification.
3. Settlements which have inadequate water supply, or for other reasons are not viable as permanent places of residence, should be moved down the priority list (unless defined plans are in place to improve the situation).

The 'rational technology' approach relies less on relative prioritisation of different settlements against each other, focusing rather on the comparative costs and benefits (financial, economic and social) of different technical options (and levels of supply) for specific settlements. As such, it is more applicable to ad hoc electrification planning, as less emphasis is placed on the generation of long-term grid plans for the entire sub-region.

Both approaches can be used to generate preliminary electrification plans for sub-regions, with budget allocations, and estimated dates of implementation (for the grid projects particularly). It is important that such plans be made public, and opportunity allowed for alteration or changes motivated by communities. This could be through clear and representative redefinition of assumed priorities. Furthermore, decisions and priority could be explicitly changed through communities gaining access to additional funds or other resources and thereby covering a portion of the costs.

Criteria for final approval of projects

The last set of criteria developed specify a number of conditions which projects should satisfy before the final go-ahead for implementation can be given. In addition to information on the financial and economic analyses referred to above, these criteria would be used to ensure that project participants:

- have an assured demand for the service offered;
- explicitly consider less easily quantified or identified costs and benefits;
- identify and utilise opportunities to maximise the benefits of electrification;
- involve the community in project implementation and operation, where appropriate;
- respect environmentally and culturally sensitive sites and impacts;
- have the necessary technical, financial, project management and community liaison capacity;
- meet quality assurance and technical standards requirements;
- ensure long-term sustainability of service provision (both from a financial perspective), and with respect to maintenance provision);
- have investigated long term grid planning in the project area and incorporated this into the project evaluation.

Utility of this work

The review material presented in this paper and the annexures should provide a useful reference for further development of planning approach and project selection criteria. Furthermore, the specific proposals for both planning approach and selection criteria that are presented can be used as a starting point and discussion basis for the further development of selection criteria for integrated grid and off-grid electrification planning by specific institutions or a future National Electrification Fund. The lack of comparative analyses of different technical options and different settlement conditions, linked to a 'real' rural electrification planning exercise, is a weakness of the work. Comparative analyses, and sub-regional, integrated planning exercises should be used to further refine and develop the selection criteria.

Acknowledgements

I would like to acknowledge the important inputs to this project provided by staff of the Development Bank of Southern Africa, Eskom, the Independent Development Trust, the National Electricity Regulator, the Department of Minerals and Energy, Refsa and the Associated Municipal Electricity Undertakings. Staff gave of their time and experience in discussions, both at the project workshops, and in follow up meetings conducted on an individual basis. In particular I would like to thank: Deon Stassen, FX Jurgens, and Paul Maré, Joe Lesenyane, T Bopela, Rodney Buttle, Sandra Bezuidenhout, Zamo Gwala, Ben Nel, Rob Stephen, Hendri Geldenhuys, Frank van der Velde, David Mahuma, Dr T Surridge, Wolsey Barnard, Ms Kosi Lisa and Ferdie Mocke. EDRC colleagues, especially Bill Cowan, Bronwyn James, Wendy Annecke and Gabriele Seeling-Hochmuth acted as attentive and stimulating soundboards. Cecile Thom (EDRC), Paul Galen (NREL) and Hilton Trollip, authors of parallel papers helped me to wrestle with the complex issues, and provided valuable input.

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List of Abbreviations

ADMD	After Diversity Maximum Demand
AMEU	Associated Municipal Electricity Undertakings
CBA	Cost Benefit Analysis
DBSA	Development Bank of Southern Africa
DME	Department of Minerals and Energy
DWAF	Department of Water Affairs and Forestry
DOH	Department of Health
EDRC	Energy & Development Research Centre, University of Cape Town
EIRR	Economic Internal Rate of Return
Eskom	Eskom (electricity utility)
IDT	Independent Development Trust
NEF	National Electrification Fund: The assumed primary source of funding for electrification.
NELF	National Electrification Forum (No longer active)
NER	National Electricity Regulator
NPV	Net Present Value
NREL	National Renewable Energy Laboratories (USA)
Refsa	Renewable Energy for South Africa
SWER	Single Wire Earth Return

1. Introduction

The Development Bank of Southern Africa (DBSA), as a member of the former Electrification Policy Co-ordinating Committee, has undertaken to draw up proposals for criteria for both strategic and operational decision-making in rural electrification (both grid and off-grid). Furthermore, the ongoing EDRC project: "The role of electricity in the integrated provision of energy to rural areas" (referred to in this document as the EDRC Rural Electrification Policy Research Project), in consultation with their steering committee, has identified selection criteria for rural electrification as being a research focus. This paper is one of the outputs of a research project that aims to address these issues, utilising resources from the DBSA and the existing Rural Electrification Policy Research project. (The larger rural electrification policy research project is funded by the DME, Norad and Eskom).[2]

The projects investigated criteria for decision-making regarding electrification from a number of points of view. We are seeking to identify a number of questions – the answers to which for a particular region or community will provide an indication of the preferred electrification method for that region or community (where electrification may mean either grid or non-grid electricity supply). Furthermore, we aim to identify criteria which can assist in the prioritisation of projects for electrification resource allocation. It is realised that the viewpoint of consumers, suppliers, and financiers may not always coincide. Thus the priority of differing criteria may vary according to the viewpoint.

Although decision criteria are required for a number of different categories of electrification projects, the focus here is on projects that will require grant funding, soft loans or some other form of subsidy to cover a portion of the costs – that is, projects that are not commercially viable in their own right. The others can presumably be identified and funded following normal business and investment practice.

The question of balance between expenditure on electrification and on other pressing needs has not been addressed as part of the project. This is a fundamental issue and does require attention, given the pressing need for improvements in a range of infrastructure and service delivery areas in the face of severe financial constraints.

The need for criteria has not been addressed in significant detail in this report. However, the following points can be made:

- It is assumed that there is a common appreciation of the need to allocate public resources of the order of one billion Rands per annum (at current rates) with care, and as objectively as possible.
- Financially, electrification of rural households and communities is a loss-making exercise. Although the viability of the electricity industry as a whole is not threatened by the programme at present, sustainability is an important issue, and care needs to be taken to ensure that projects are prioritised in areas where there is a greater probability of return.
- Given the significant subsidy inherent in the current grid electrification programme (of the order of R3500 per customer), allocating of grid electricity to only some households or communities is, in effect, to grant national resources in an extremely uneven manner: some get, and some do not. This is

2 This criteria project has a similar in scope to a larger research proposal submitted for discussion to the Electrification Policy Co-ordination Committee. Although members of the committee indicated support for the original proposal, the necessary funds were not been secured. The current project thus has fewer final outputs, and a more limited scope of activities than those originally proposed, to enable completion using available resources.

intuitively unfair, although it may be justifiable if decisions are made in a rational and transparent way.

- It is essential for communities and implementation agencies to know with some degree of urgency and certainty what the grid electrification plans for the next five to ten years will be. Otherwise unelectrified areas will tend to stagnate, with both the communities and development agencies unwilling to invest in alternatives to grid electricity, waiting hopefully for the grid to appear next year, in five years time or never.[3] To date this has resulted in many off-grid endeavours taking place in very remote areas, where the probability of grid electrification is correspondingly low. These areas are often the poorest, and thus the most difficult in which to achieve success. The best place for off-grid development to take place would be those settlements which *almost but do not quite* qualify for grid electrification; they are likely to have higher economic potential than more remote communities, and should be identified as early as possible.

1.1 Report structure, and context of this paper within the larger project

This paper focuses on operational level planning criteria. Consider a specific region, such as illustrated in Figure 1. The key questions tackled are:

- Which settlements in a region should be electrified using the grid?
- Which settlements in a region should be electrified using off-grid technology?
- What conditions should either grid or off-grid projects satisfy before actual project implementation can be approved?
- How should electrification projects be prioritised relative to each other?

The paper has four chapters following this introduction. Chapter Two briefly reviews the different electrification options (technologies) that are expected to play a significant role in South African electrification efforts. Chapter Three is an overview of current electrification decision-making issues and criteria. Chapter Four considers the information requirements necessary for electrification planning decision-making, and reviews some of the analysis tools used to process and aggregate information into a manageable form. The last chapter draws on the preceding work, and presents for debate a decision-making approach, and appropriate criteria to support electrification decision making.

Annex B presents a more detailed review of current electrification decision issues and criteria, as used by key institutions in South Africa.

Two related papers are also outputs of the project:

- Electrification Decision Points Report. Prepared by Paul Galen of NREL. 1998. This paper reviews international experience, seeking to extract lessons for South Africa.
- Criteria for the allocation of electrification resources to regions and provinces: In preparation by Cecile Thom. EDRC 1998.

The DBSA and Eskom have also commissioned Hilton Trollip to conduct a study of the available GIS and other database resources, and to explore the potential for such data resources to be used in electrification decision-making.

1.2 Methodology

The research process has involved consultation and discussion with a number of key players involved in electrification planning. Two workshops were held, as

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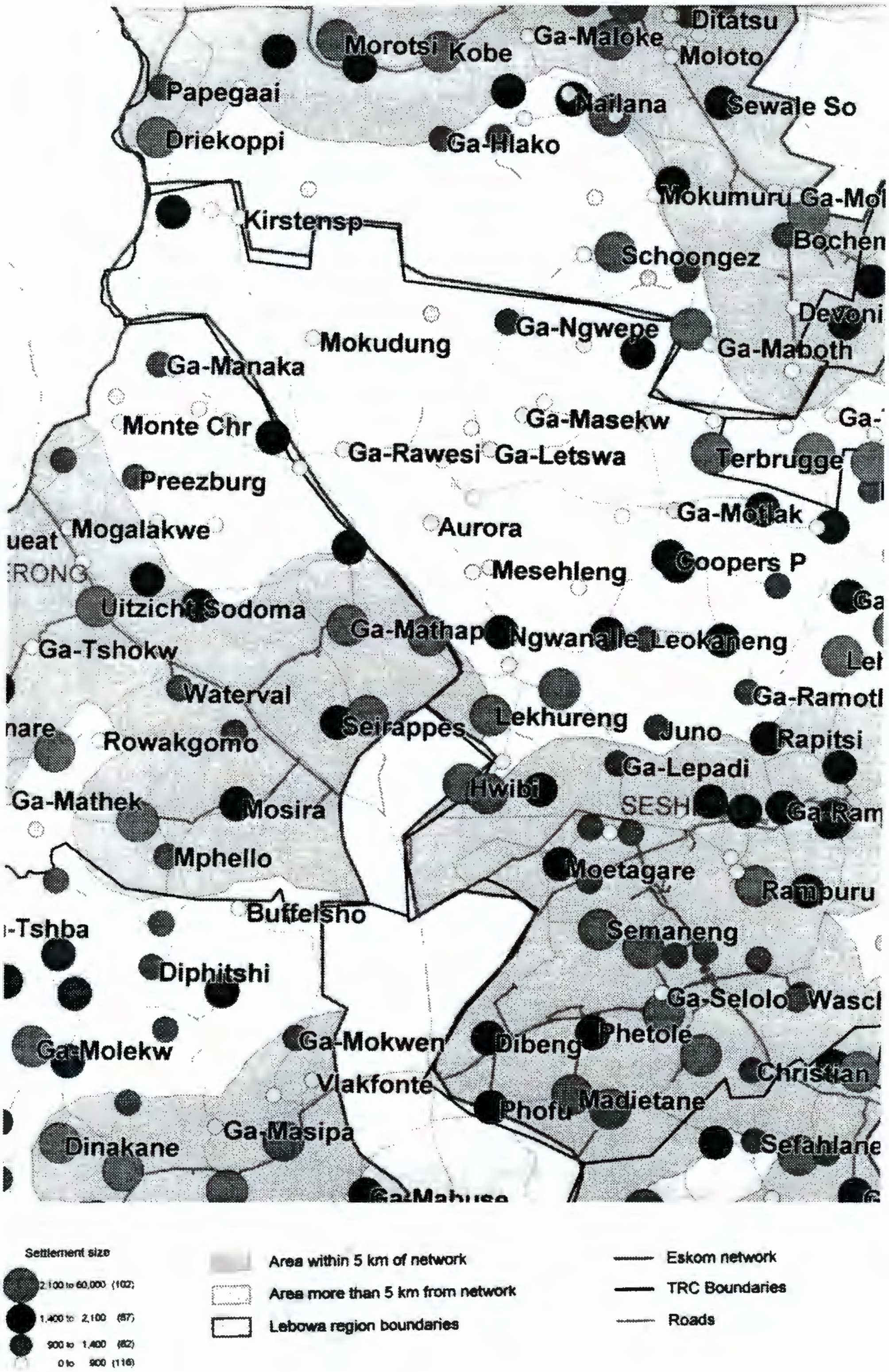
3 Investments in off-grid technology are by and large sunk, and indeed wasted if grid electrification subsequently takes place (unless these investments can be absorbed by the utility, or moved to other areas on a cost effective basis).

discussed below. Furthermore, the research team has had access to position papers, some internal documents, and research reports on matters of relevance to electrification planning and decision processes. The workshops provided important information input, and these were followed up through more in-depth discussions.

Figure 1. Which settlements should be electrified, when?



1.2.1 Initial workshop

An inception workshop was held at the DBSA on 15 October 1997. This was attended by staff from the DME, DBSA, NER, Eskom electrification planning and the Non-Grid department, AMEU, IDT, Refsa, and the project research team (EDRC and NREL). The objectives of the workshop were:

- to introduce the project scope and objectives;
- to establish a working relationship between the research team and key role players;
- to identify related activities which are taking place that could support the process; and
- to provide an opportunity for written or verbal input on decision making criteria.

Key factors which emerged are as follows:

- There is currently no clear electrification policy, and at present it is not clear how the policy process will be taken forward. This makes the development of criteria to support decision-making difficult.
- There are significant tensions between different types of criteria. For example, there is a strong motivation for least-cost electrification planning at present within Eskom, resulting from a strong commitment to agreed quantitative targets, coupled with limits on resources. This does not facilitate planning along development potential lines, and could also make decisions based on equity considerations difficult.
- Political forces in electrification planning were highlighted, and it was noted that Eskom is exposed to, and influenced by, very significant political forces, both at the local level, and at higher levels (parliament, senior officials).
- Grid and off-grid electrification planning, and the criteria used in decision-making for planning are highly topical and relevant, and at the heart of electrification policy implementation and delivery.

1.2.2 Second project workshop

The second project workshop took place on 5 February 1998, and was attended by staff from DME, DBSA, the NER, MEGASUB, AMEU, the IDT, Refsa and Eskom. Cecile Thom, Hilton Trollip and Paul Galen were also present, as authors of the parallel papers. The workshop provided a useful opportunity, not only for feedback of the preliminary results of the study, but also for a closer look at the potential role of GIS based planning tools in supporting decision-making. More specific reference to the latter is presented in section 4.1. Discussions at the workshop were wide ranging, and an attempt has been made to incorporate comments and issues into the body of this report, and that of Thom (1998).

2. An overview of rural electrification

2.1 The electrification programmes

At present, there are four principal ways in which electrification is being implemented on a wide scale in South Africa. These are all in line with Reconstruction and Development Programme (RDP) targets, set through deliberations of the National Electrification Forum (NELF) process.

1. Eskom is financing and managing a large-scale rural electrification programme, which involves annual investments of the order of R1.1 billion to achieve approximately 300 000 household connections per annum. These currently take place primarily in rural areas (as Eskom does not have distribution rights in the majority of urban areas). This programme has been financed through the issue of Eskom 168 Bonds, a large loan through the DBSA (R 750 000 000), and external grant funding. Operational losses are currently covered within Eskom, effectively through cross-subsidisation. Eskom has raised the capital required directly, and is therefore the final decision-maker for the majority of rural electrification projects.
2. Local authorities are engaged in electrification of urban areas and some rural areas which fall within their designated area of supply. The NER manages the disbursement of approximately R300 million (for the 1998 programme) to support electrification by local authorities. These funds were made available by Eskom as a contribution towards levelling the playing field between Eskom distributors and local authority distributors (NER 1997b). The DBSA is being used as a banking facility for disbursing these funds. Local authorities have also raised finance from other sources (including the DBSA).
3. Eskom is currently involved in the electrification of schools (using grid and off-grid technology). Funding for this has been primarily through Norad, and the RDP. Roll-out rates are given in **Table 1.**
4. The Independent Development Trust (IDT) has an active clinic electrification programme underway. This has involved supplying grid and off-grid solutions to satisfy the high quality energy demands of rural clinics and clinic staff. Eskom have also connected a number of rural clinics, as indicated in the table below.

Progress in the above initiatives has been widely reported – see Davis (1996), or annex A of Davis et al (1996) for review material.

Work in off-grid household electrification projects has been less active than in the clinic and schools programmes. Off-grid household electrification projects have already been implemented in the Free-State (Hochmuth & Morris, 1998), and in KwaZulu/Natal (Hochmuth 1996; Cawood 1997). Pilot projects using central battery charging stations have also been implemented (Hochmuth 1997a). A number of organisations have been preparing to engage in larger-scale pilot project off-grid community electrification projects. However, recent developments regarding the locus of government support and financing have resulted in further delays.[4] Other key implementers are Eskom (through their Energisation programme, supported by Eskom NGE), the IDT, and as yet unspecified private sector initiatives. The DME also has pilot project proposals developed to a fairly advanced stage.

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[4] Refsa had a government mandate to fund and facilitate such activities. However, late in 1997 a decision was taken to move the government supported activities from the quasi-independent Refsa back into the Department of Minerals and Energy.

	1991/2	*1993*	*1994*	*1995*	*1996*[1]	*1997 (app.)*	*1998 planned*
Eskom prepayment connections	177 000	209 000	254 000	313 000	307 000	270 000	300 000
Local government connections	93 000	91 000	130 000	118 000	126 000	150 000	150 000
Other	21 000	16 000	35 000	32 000	11 500	-	-
Farmworker connections	0	16 000	17 000	15 000	9 500	-	-
Total	291 000	332 000	436 000	478 000	454 000	-	-
Eskom capex (R'000)	R472m	R584m	R808m	R1 055m	R1 049m	R890m	R 819m
Eskom capex per connection	R3 036	R2 799	R3 179	R3 370	R3 417	-	R2 734
Schools – grid[2]	85	240	562	990	1028	350[3]	-
Schools – off-grid[3]	App. 14			57	989	196	1000
Clinics – Eskom[2]	13	16	21	37	16	28	-
Clinics – IDT programme (grid)[4]		Approx. 210 to end 1997					-
Clinics – IDT (off-grid)[4]		13	15	30	50	50	50+

Notes:

[1] NER (1997a: 14); [2] Bopela T (1997); [3] Bezuidenhout (1998); [4] van der Velde (1998)

Table 1: Electrification progress to date
Source: Davis (1996) and other sources as indicated in notes

Each of the above initiatives currently implements its own electrification planning process. In rural areas, the Eskom settlement electrification process is dominant, both in terms of scale and because there is generally a strong preference expressed by communities for grid electrification, rather than off-grid electrification. A key objective of off-grid planners is usually to obtain clear statements from Eskom regarding future plans for grid extension. For a variety or reasons long-term plans for grid electrification are not readily available. Due to uncertainty regarding grid extension plans, off-grid implementers are often forced to operate in areas very remote from the grid, where the chances of the grid approaching over the hills are very low. Since these more remote areas are often poorer, this has a negative effect on the economic viability and sustainability of off-grid electrification projects.

2.2 Electrification policy and restructuring of the industry

There is currently no formally accepted national electrification policy. As noted above, a series of targets have been established for the national electrification programme which, in effect, define the scale and main policy directive. While the RDP programme sets out guidelines for RDP-type projects, the nature of the funding for electrification has meant that the programme is not bound to these policies. There are no national policies regarding the level of service to be provided in electrification projects, or regarding selection procedures and priorities and the implementation agencies have therefore had to play a *de facto* role in establishing and implementing electrification policy. The situation is however in a state of flux, and changes are taking place:

- The electricity distribution industry will be restructured. Although the process and form of restructuring is currently under debate, it is probable that the (urban) local authority electricity distributors and Eskom will be merged and then divided into an as yet unknown number of regional electricity distributors (REDs). Individual REDs would thus have responsibility for urban and rural area distribution.
- Eskom will be taxed,[5] and will be expected to pay dividends. Revenue generated through this process would thus be available to the fiscus, and the

[5] A bill to this effect has been approved by cabinet, but has not yet been passed into law or implemented.

intention is that this would be allocated to electrification implementation agents (REDs and possibly others).

- Responsibility for electrification financing would thus be separated from the industry, and could then be reallocated according to broader national priorities and policy.
- Government is playing a significant role in the industry restructuring process, and it is expected that an electrification policy will be developed.
- The NER is expected to play an increased role in both electrification resource allocation, and in industry restructuring.

2.3 Rural electrification – what are the options?

Prior to discussing the decision-making process, and applicable criteria for electrification, it is important to establish an understanding of what is meant by electrification. This report does not seek to provide in-depth analysis of the electrification options, but salient points of the different community electrification options are raised below.

2.3.1 Grid electrification

Rural grid electrification is currently being carried out by Eskom on an unprecedented scale. Communities are generally connected through phased electrification projects – with near-blanket coverage being achieved within the more dense settlements. In certain parts of the country (particularly KwaZulu/ Natal), the dispersed nature of households makes blanket coverage difficult, and corridors which allow Eskom to achieve the target number of connections at least cost are electrified. The standard household connection has a capacity of 20 A, with metering and billing implemented using a prepayment system. Capital costs vary, with a minimum per household of approximately R1400 being achievable in very dense areas with structured housing layout. Early on in the programme costs per connection of over R5000 were tolerated in some rural areas; currently, costs per connection acceptable to the planners are of the order of R3800 or less. A variety of technologies have been employed to keep costs as low as possible. At the MV level, single wire, earth return systems (SWER) are being mooted. In certain areas, Eskom has implemented a limited current supply option (2.5 A) using a flat-rate monthly tariff. Pilot projects have had mixed results (see James 1997). Recent discussions indicate that a mixed supply option will be considered, whereby some customers would pay a premium to receive the normal 20 A supply, while others (particularly those further from the distribution transformers) would be offered a limited-current supply at a flat-rate tariff.

Although the 20 A connection option can provide sufficient energy to meet thermal as well as lighting and entertainment needs, experience to date has indicated very low consumption levels (Davis 1995; James 1997). Electricity is primarily used for lighting and entertainment, or for convenience short-term cooking requirements. Operational costs are thus generally not being covered at present and the prospects of recovering capital investments are remote.

Once the presence of the grid has been established in a community, it does allow increased scope for business activity (subject to constraints such as access to finance, market and skills availability). Furthermore, benefits to clinics, schools, water supply projects and agricultural projects can be expected if the necessary infrastructure exists and planning co-ordination is effective (Borchers & Hofmeyr 1997).

2.3.2 Off-grid options for electrification

Where the grid is not selected as an option for a community (or where only some community members receive a grid connection), the current norm is for little or no externally mediated energy initiative to take place in the community. No other energy option currently receives similar effective subsidy. The decision not to electrify thus carries considerable implications for the community. However, a number of other options are receiving increased attention from government, the former Refsa, the IDT, the private sector, Eskom, and (in some cases) international initiatives. Although active programmes have been initiated, as noted above, for school and clinic systems, household non-grid electricity provision options are currently only at a pilot project stage. Different technical, institutional and delivery models are being explored, and it is not yet clear what off-grid electrification really will offer to households and communities, or at what cost this will be to householders. In order to establish a common understanding for debate, the principal options being considered are briefly described below.

2.3.2.1 Solar lanterns

Solar lanterns are small (3-10 Wp) systems comprising a lamp and battery mounted in a portable holder. The module is usually mounted separately, and should be connected to the lantern during the day. At night, the lantern can be moved around, as light is needed. Lanterns have the potential to reach a larger market than solar home systems (SHS), as their costs are significantly lower, and they can thus be afforded by a greater percentage of rural dwellers. A true mass market has however not yet developed, for similar reasons to that of SHSs.

A field trial of a number of different models in Kenya (Hankins 1996) yielded promising results:

- The demand for solar lanterns from customers, at the project prices (US$ 40 – 100), was greater than the available project supply.
- Customers valued the light output of the lanterns, and their expectations of light output grew rapidly.
- Some lanterns were able to power radios. This was considered a valuable feature.
- Consumers appreciated being able to chose between different lantern models.
- There were some technical/design problems with existing models available on the market, with the biggest problem area being battery life.
- There is room for reduction in lantern pricing (import tariffs, bulk purchasing).
- As with SHSs, there is a potential for improvement of the market through better publicisation, financing, standardisation, improvement in the availability of spares, greater information dissemination to dealers regarding product performance and capability.

Solar lanterns have not been significantly explored as an option for communities in South Africa yet.

2.3.2.2 Battery charging stations

A number of centralised battery charging stations have been installed as pilot projects, primarily through a private sector initiative of Golden Genesis Africa. Evaluation is currently being carried out, through a DME-funded project (Hochmuth 1997b). In such systems, a central charging station, typically powered using photovoltaic arrays, is established as a commercial venture in a community or region. Householders can then purchase (often using a loan) kits comprising a battery, battery box, load shed unit (to protect the battery from severe discharge) and one or more DC fluorescent lights. Costs of such kits range from R750 to R1450 per household (Hochmuth 1997b). The systems can then be used for lighting, and to power radios, small monchrome television sets, and hi-fi sets. The batteries are recharged at the central station for a fee (currently of the order of R10 per charge, although this may be reduced). Time between charges will obviously depend on the level of energy consumption. However, if one light and a small TV are operated for three hours and one hour respectively per night, recharging would be required approximately once per fortnight, with a monthly cost for charging of R20. Capital redemption charges would be an additional R25 (R750 at 17.12% over 3 years, Hochmuth 1997a)

Significant numbers of rural households already utilise lead-acid batteries to provide power for TV, radio or hi-fi sets. Charging stations using diesel generators, or more typically grid power can be found in a number of regions. Costs of charging are in the order of R7 per charge, and it should be noted that there are usually significant additional costs in terms of both travel time and travel fares to users (Hochmuth 1997a). Householders with vehicles can also use them to charge batteries while driving.

Battery charging stations utilising the excess capacity of school or clinic solar electrification schemes have also been considered, particularly as revenue from charging can help to improve viability of the community facility maintenance and operation.

Currently, there are no formal programmes in place to utilise battery charging as an electrification option on a large scale, and no subsidy is available to reduce the capital costs to users or to the charging station owners.

Battery charging stations using solar or other energy sources have been utilised on a significant scale in some parts of the world. Hochmuth (1997a) reports that 500 stations are being installed in Brazil, and that 34 stations were set up in Columbia by 1993.

2.3.2.3 *Solar home systems*

Solar home systems typically comprise a solar photovoltaic panel, battery, charge controller, two or more fluorescent lights, and a plug point for a television set. A standard system costing in the region of R3500 will provide sufficient energy to operate three lights and a small monochrome television set for four hours per day. Running costs should be low, and include maintenance, checking of battery water levels and replacement of lights as necessary. Battery replacement will be a significant cost approximately once every three years (as for battery charging systems described above).

Attempts to establish pilot projects for SHS dissemination have been frustrated, primarily as a result of institutional developments in the sector, difficulties in establishing adequate rural financing schemes, and in some cases an unwillingness on the part of householders to accept the technology, given current high expectations of grid connections.

A pilot project in KwaZulu/Natal has been in operation for 18 months, and experience has been documented (Cawood 1997; Hochmuth 1996). The farmworker SHS activities in the Free State have also recently been evaluated (Hochmuth & Morris, 1998). There is, however, a serious lack of field experience in South African conditions on which to base sound policy making, and particularly to use in the development of criteria.

A number of different models for SHS financing and dissemination have been proposed and are being explored. Four models of SHS dissemination were being explored by Refsa during 1997, in partnership with other organisations and the industry:

1. *Community-based model*
   This approach may be implemented by the IDT, and is likely to use community structures and collective loan finance as the main interactive method and financial management tool.

2. *Intermediary finance approach, linked to the Eskom Non-Grid Electrification and Eskom Energisation programmes*
   In this model Eskom would be the main implementation authority. Financing would be through a finance organisation operational in the project area. Close links to the Eskom Energisation project would be used to broaden the package of options delivered to include a gas stove and gas bottles – thus aiming to meet a larger proportion of the communities needs through the programme. As with option 4 below, the approach will rely significantly on an individual or rural trade store as a service point (an energy agent).

3. *Industry-led approach*
   There are a number of active players in the photovoltaic industry who clearly have a strong vested interest in seeing a successful SHS programme emerge. These businesses, if given suitable support, and subject to appropriate auditing, could establish rural SHS projects and possibly act as channels for credit or subsidy schemes.
4. *Rural energy trade store approach*
   Rural entrepreneurs can provide a channel for energy goods such as paraffin, LPG and SHSs. They are also well placed to act as channels for credit to householders. A number of options are being explored to train and utilise such rural traders as the backbone of rural SHS delivery schemes.

A fifth approach to SHS dissemination is the so called 'utility approach'. In this model, an energy agency would retain ownership of the solar modules and some of the in-house components. A monthly fee would then be charged on a long-term basis for the energy service delivered. This model reduces the risks considerably for the householder, and they can return the equipment at any stage with little loss.

Regarding market penetration – unlike current grid electrification projects, where most people in a community tend to apply for (and get) connections, the take-up rates for solar electrification tend to be far lower. Most dissemination models being considered assume that a significant deposit will be required, and the relatively high monthly charges mean that only 10 or 20 per cent of the households can afford systems.

Despite the relative lack of success with SHS dissemination to date in South Africa, the technology is generally considered to be the best alternative to conventional grid electrification for domestic lighting and entertainment needs. There is considerable international experience of SHS dissemination. For a comprehensive review, including an analysis of the market potential, see Cowan et al (1996a).

2.3.2.4 Mini-grid

A number of renewable energy experts have proposed that mini-grids should be considered as electrification options – particularly where settlements have reasonably high household densities, and where there are significant major consumers who require higher supply capacity (more than 2 kWh per day).

Mini-grid systems can be powered using a range of technologies including wind, solar PV, solar thermal electric, diesel and micro-hydro. The most cost-effective solution will often involve a combination of energy sources – a hybrid system. A mini-grid system would typically be designed to provide power for productive activities such as welding, light engineering, crafts, as well as domestic loads, making it, of all the non-grid options, closest to conventional grid electrification. Furthermore, unlike SHS or battery charging systems, a mini-grid system would typically use AC 220 V appliances and wiring, thus making connection of the entire system to the national grid at a later stage a relatively simple process. Such connection need not result in the demise of the primary generation source, as distributed generators can feed energy into the national grid (provided that the utility develops appropriate power purchasing agreements).

2.3.3 Costs of electrification options

Both capital and life-cycle costs will clearly play a significant role in electrification decision-making. These costs vary, depending on the level of supply required, and a number of different settlement characteristics. Table 2 provides an indication of the key settlement or regional specific variables which will tend to alter costs for the different technologies.

Table 2 Key settlement characteristics that affect electrification costs on a per connection basis.

Characteristic	*Prepayment option (20 A or greater capacity)*	*Limited current supply – fixed monthly tariff*	*Battery charging systems*	*Solar home systems*	*Mini-grid*
Distance from existing grid with sufficient bulk supply capacity	Increases in direct proportion	Increases in direct proportion- at lower rate than for 20 A supply	Not affected	Not affected	Not affected
Density of households (hh/km^2)	Costs reduced as hh density increases	Costs reduced as hh density increases	If consumers far from charging station- transport can become an issue	Negligible effect on costs	Costs reduced as hh density increases
Settlement size	Costs reduce for larger settlements	Costs reduce for larger settlements	Modular approach – cost per user not strongly affected by settlement size although viability of charging station as income source will depend on adequate number of customers	Modular approach- costs independent on settlement size. However loan management, installation, and maintenance require a reasonable number (40) of households in area	Can be utilised for a range of settlement sizes, although costs will reduce for larger settlements.
Proximity of settlements to each other	Cost of bulk supply reduces if settlements close to each other.	Cost of bulk supply reduces if settlements close to each other.	Little effect. Service and finance costs may be reduced	Little effect. Service and finance costs may be reduced	Little effect. Service and finance costs may be reduced
Topography	Costs increase in very hilly areas	Costs increase in very hilly areas	Not sensitive to topography	Not sensitive to topography	Costs affected by topography in similar manner to grid
Average demand	Financial viability (for utility) improves as demand increases.	Financial viability (for utility) minimally affected by demand up to 2.5 A (560 Watt limit). If consumer wants to increase demand further- requires upgrade	Monthly costs to consumer increase in proportion to energy use	Capital costs increase approximately in proportion to demand. Given system has fixed daily energy availability fixed	Capital costs increase approximately in proportion to average demand –some economy of scale. Systems usually have better medium demand capability than SHS systems.
Demand variability (short term peaks	Well suited to demand variations within certain maximum demand limits	Peak loads limited to 500 W	Can provide short term high power, but typical application does not require this.	Larger systems can tolerate very short-term medium power demand (e.g. an 1 to 3 kW inverter running power tools)	System can usually tolerate short term high demand (using genset or battery bank) more readily than stand alone systems.
Demand variability (load factor)	Return on capital investment significantly affected by poor load factor	Load factor can be more tightly controlled	If energy not used – poor return on capital investment	Costs for a given system almost independent of energy use. If over design severe cost penalty	If diesel only, poor load factor will increase energy cost significantly, and may reduce engine life. Hybrid systems better suited to

					cope with poor load factor.
Characteristic	*Prepayment option (20 A or greater capacity)*	*Limited current supply – fixed monthly tariff*	*Battery charging systems*	*Solar home systems*	*Mini-grid*
Demand variability (gradual increase in load)	Depends on the design ADMD – usually caters for significant load growth. Some component may need to be upgraded (transformers)	Upgrade required for significant changes in demand. If wide spread, may require replacement of transformers and possibly additional lines	Cost of recharging (and battery replacement) will increase in proportion to energy uses. System is reasonably module and can be upgraded to SHS	Systems capacity can be increased on modular basis. However high average demand (refrigeration, thermal) are expensive or uneconomical to meet	Systems are usually modular – capacity can be increased. If significant increase in demand, then system can be linked to national grid
Demand uncertainty	ADMD has to be estimated with reasonable accuracy as it is expensive to upgrade and seldom worthwhile to downgrade	As for prepayment option	If load increases unexpectedly, systems are modular. Depending on technology and delivery model, upgrade to SHS can be achieved at reasonable cost.	Systems are modular, thus adjustments can be made. If settlement demand changes significantly, can be considered as a pre-grid-electrification process	Systems are usually quite flexible, and gensets can be removed or added reasonably easily.
Typical costs[6]:					
Capital (installed)	R3000	R2700[7]	R750 to R1500 for hh kit.	R2800	Data not available
Op. and maint (supplier).	R 21	R12 or more	variable	Approx. R16	
Customer cont. to capex.	Little contribution	No contribution	R25 (R750 over 3 yrs)	With R1500 subs: R42 /m	
Energy charge to customer	30.79c/kWh, app. R24/m	R10/month -pilot	R10 to R30	R 0	

[6] Costs are given as rough indicators only. There can be significant variations according to project conditions and financing approach.

[7] Although load limited supply can be up to 33% cheaper than a 20 A supply, the option is more likely to be used for remote households, or less dense settlements, where the typical costs would be higher.

2.4 Benefits

2.4.1 Comparing the benefits of different electrification options

Quantitative comparisons of different electrification options can be made for a number of factors such as ability to meet load, flexibility of supply, versatility, costs of energy, suitability for specific tasks, and (to a certain extent) reliability. A number of benefits are far less tangible, however, and need to be addressed through qualitative and quantitative assessment of the impact of different electrification options at household and community level in specific cultural and socio-economic contexts.

Clearly, in electrification decision-making processes, it would be preferable to have information on benefits readily available. This is, however, a subject requiring considerable research, and there is, furthermore, considerable debate regarding the expected and actual benefits of electrification projects. For the present, **Table 3** below provides a qualitative indication of the difference in benefits for different technology options. The actual benefits realised by households as a result of electrification will depend significantly on the tariffs applied, and the manner in which charging is carried out. For example, it has been found that regular monthly payments are difficult for many people to achieve, the prepayment meter option allows better user management and realisation of benefits.

The benefits of community electrification (households, businesses, education facilities, clinics, etc) can sometimes only be realised if other parallel developments takes place (access to finance for appliances, finance and markets for businesses, evening classes or education materials in schools, improved water supply for a community or clinic). The context in which electrification with a particular technology option takes place is thus also of vital importance.

Table 3: Comparative benefits of different electrification technologies

Area of benefit	*Grid (20 A)*	*Grid (2.5 A)*[8]	*Off-grid systems*
Health			
Vaccine storage at clinic	Refrigeration temperatures and reliability improved	N/A	Comparable (Assuming clinic equipped with solar refrigeration system)
Cooking (in households)	Possible benefits especially for wealthier households (environmental) but often slow uptake.	Cooking currently not possible – parallel energy supply activity required	Cannot contribute – parallel energy supply activity required
Water supply pumping (to clinic and households)	Easier with grid, especially for larger quantities	N/A	Possible using PV, diesel, other
Paraffin poisoning (of children in households)	Potential impact, although has often not been significant	Little impact (except through better education)	Little impact (except through better education)
Communication –mass media	TV, radio	TV, radio	TV (usually smaller, B&W), radio
Communication – person to person	Telephone or two-way radio possible	Telephone or two-way radio possible	Telephone or two-way radio possible
Education			
Lighting in school – (marginal benefit, depending on level of evening activity)	Grid and off-grid provide a similar level of service.	N/A	Grid and off-grid provide a similar level of service.
Media (video and TV in schools)	Grid and off-grid provide a similar level of service.	N/A	Grid and off-grid provide a similar level of service.
Overhead projectors	Can be used	N/A	Can be used, although not for extensive periods.
Computers	Can be used	N/A	Can be used although not at

8 It is assumed that a higher rated connection would be supplied to schools or clinics, even if the majority of households are equipped with a limited current supply.

			same scale as for grid.
Photostat machines	Can be used	N/A	Unlikely to be used
Domestic Science, Science	Electric stoves can be used to facilitate teaching and practice	N/A	Non-electrical energy source required for cooking
Nutritional: improved cooking at home or for school feeding schemes	Improvement possible	Non-electrical energy source required for home cooking	Non-electrical energy source required for cooking
Productive activities			
Productive uses of electricity	Energy source is readily available, and can facilitate a range of business activities	Limited current supply can facilitate some business (entertainment, public space lighting). However, most business activities would require upgrade. Given grid availability this could normally be carried out at relatively low cost.	Off-grid options can readily supply public lighting and musical entertainment needs. Refrigeration, and business activities requiring higher power require significantly more expensive investment. If loads are in the multi-kilowatt range, then diesel, with attendant high running costs will normally be required.
Agriculture - water pumping for stock	Grid availability can facilitate	Grid availability can facilitate	Off-grid can be economical solution
Agriculture - water pumping for irrigation	Grid power can yield significant economic returns	Grid power can yield significant economic returns	Smaller quantities can be economically pumped using PV or wind. However, for larger quantities diesel will be cheaper, but still expensive compared to the energy charge for a grid supply.
Household			
Lighting	Low cost lighting from grid	Fixed cost- good access to lighting	Fixed cost – reasonable access to lighting
TV	Can be used	Can be used	For average SHS system B&W only. Costs increase if larger or colour TV to be used for extensive periods
Radio	Can be used, although often not due to voltage incompatibility	Can be used, although often not due to voltage incompatibility	Can be used, although often not due to voltage incompatibility
Hi-Fi	Can be used	Can be used	Can normally be used, but depends on power rating of Hi-Fi. May require AC (inverter)
Ironing	Can be used once appliance purchased	Can be used, but appliances less readily available	Alternative energy source required (gas, biomass, paraffin)
Heating water	Can be used, usually for small quantities (tea)	Appliance not readily available	Alternative energy source required (gas, biomass, paraffin)
Cooking	Can be used – although many customers do not cook extensively using grid	Alternative energy source required (gas, biomass, paraffin)	Alternative energy source required (gas, biomass, paraffin)

Source: Borchers and Hofmeyr (1997) used as the principal reference for above table

3. Planning framework and review of existing criteria

3.1 Resource allocation process and planning process

It is extremely difficult to conceptualise and analyse criteria without having a clear understanding of the electrification planning framework within which the criteria are or will be applied. A number of key decision-making and planning processes are envisaged:

- *Regional allocation (to different provinces, or possibly to different REDS or licensed distributors)*
  Resources should be allocated to different regions using strategic allocation criteria. This will then provide a definite planning framework within which they can work. (See Thom (1998) for a discussion of the criteria to be used for *regional level allocations.)*
- *Technology-specific allocations (to grid, or to off-grid)*
  In order to provide both the grid and the off-grid industries with a measure of planning certainty, a portion of the national electrification resources may be allocated to grid, a portion to off-grid, and a portion may be unspecified, simply allocated to electrification This pre-allocation could alternatively be based on a decision regarding the level of supply rather than technology.[9]
- *Sub-regional allocation*
  Within the defined regional allocations, planning authorities will have to allocate resources to sub-regions, again aiming to provide a defined resource base that can be used for planning.
- *Settlement allocations*
  Within sub regions two sets of decisions are required:
  a) Technology choice – which is the most appropriate technology for settlements in that sub-region?
  b) For both grid and off-grid projects, how should settlements be prioritised for electrification?

The flow of these decision processes is illustrated in **Figure 2**.

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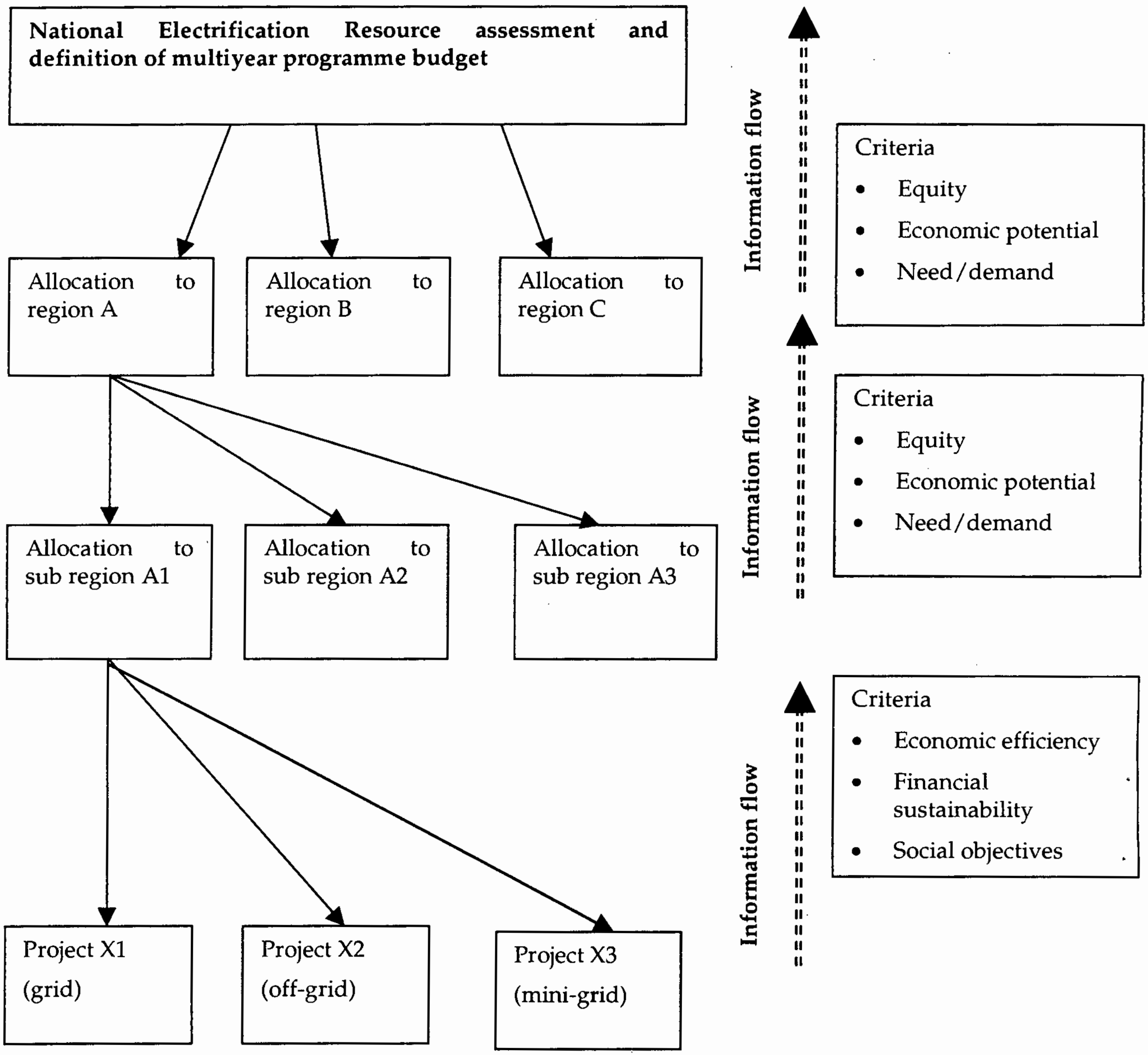
9 The necessity of this stage in the resource allocation process can be debated (see section 5.1.9).

Figure 2: Illustration of resource allocation process



The above figure provides a simplified representation of the resource allocation process, and the type of criteria that are applicable at the different levels in the allocation process.

Two important additions should be considered.

- As discussed by Thom (1998), a separate budget could be allocated at the national level for MV and HV transmission and bulk infrastructure development. Allocation of this resource, although still based on equity, economic efficiency and need, would rely on different data and information sets.
- Secondly, if there is an explicit allocation of resources to off-grid electrification at a national level, this would require a similar, but parallel resource allocation process.

The allocation process described above represents the first level at which criteria are required. A second level of criteria are required for final acceptance of projects onto fixed project plans.

3.2 Review of criteria used by the major institutions

The criteria used by the principal institutions involved in electrification planning have been reviewed in some detail, and are documented in Annexure B. Key elements are highlighted below.

3.2.1 Emphasis on grid planning

There is an emphasis on grid electrification planning and prioritisation. Data resources and planning processes are primarily concerned with identifying settlements to be electrified using the grid during the next year or, at most, two years. There is little acknowledgement amongst grid-planning authorities of the significant negative impact that lack of longer term, public, grid plans have on off-grid planning. Off-grid planning is highly dependent on information about the grid, and future grid extension plans. The most important indicator of off-grid technology suitability is a significantly higher relative cost in financial or economic terms for grid electrification. Given the short-term focus of grid electrification planning, detailed information on longer-term grid electrification planning is not readily available. As a result off-grid planning is risky, and sometimes invalidated by the unexpected arrival of the grid.

3.2.2 Capital costs

Minimisation of capital costs per connection is the main selection criterion within the Eskom-dominated rural electrification programme, primarily as a result of the target-driven nature of the programme, coupled with an appreciation that the programme is not financially viable, and a perception that the principle way to minimise losses is to minimise the initial investment. This means that settlement characteristics that are indicators of the capital cost of grid electrification are most important in early project identification and selection. These include:

- distance from existing grid (which has sufficient capacity or the estimated cost of upgrading bulk supply);
- spatial layout of households (density or expected number of connections per km of line);
- settlement size;
- proximity of settlements to each other; and
- to a lesser extent, housing structure.

Importantly, there is also a perceived link between capital costs and a number of other settlement characteristics. For example, income levels, and infrastructure levels (roads, water supply, health service facilities) frequently drop off with increasing distance from the existing grid infrastructure. Similarly, communities which have houses that are spatially clustered and organised along a rectangular grid pattern (and are thus cheaper to electrify) are also perceived by some to present a better bet in terms of expected electricity consumption and willingness to pay.

3.2.3 Financial and economic analysis

Both Eskom and the DBSA use a shared economic analysis model. The current version has a been extended from a base developed by EDRC and documented by Davis and Horvei (1995). Subject to certain qualification regarding the reliability and appropriateness of data used (see section 4.3.2), the tool does provide a potentially useful indication of project financial viability (from the utility perspective), and of the potential economic costs and benefits to society as a whole. Typical output of the model and guideline project requirements are listed in **Table 4**. In principle, project approval is only for projects which have a positive financial NPV and an economic internal rate of return greater than 6%. (For the DBSA loan to Eskom of 1997, the requirement was that the programme should indicate a positive economic net present value at a discount rate of five per cent (DBSA 1997)). While the latter condition is frequently met, the financial NPV is seldom greater than zero[10]. The CBA tool is primarily used by Eskom as a project acceptance/rejection criteria, rather than being used as one of the inputs for prioritisation.

At low consumption levels, the capital cost of electrification is the most significant contributor to the life-time costs. Given the uncertainty regarding consumption growth, this is an important reason why Eskom focuses on capital cost minimisation as the primary project selection criterion.

Table 4: Typical CBA model results

Financial results:	*(LRMC)*	*(SRMC)*	*Requirement*
Net present value (R '000):	(R1 910)	(R2 223)	NPV > 0
Net present value/customer:	(R2 011)	(R2 340)	NPV ≥ 0
Internal rate of return:	6.8%	3.2%	IRR ≥ 15.5%
Cross-subsidy required:	5.2 c/kWh or R7.18 per customer /month		
Economic results:	*Ave costs (LRMC)*	*Marginal (SRMC)*	*Requirement*
Net present value (R '000):	R865	R547	NPV > 0
Net present value/customer:	R910	R576	NPV ≥ 0
Internal rate of return:	9.6%	8.5%	EIRR ≥ 6%
Benefit to cost ratio:	1.23	1.13	BCR ≥ 1

3.2.4 Regional variation and equity in target allocations

There is significant variation in the average costs per connection, and in the allowed costs per connection in the different regions of the country. This variation in the allowable costs per connection means that the emphasis on reducing the capital costs per connection is modified through acknowledgement of the need for a measure of regional equity or fairness in resource allocation. See Thom (1998) for further discussion of this issue.

3.2.5 Expected consumption, consumption growth and willingness to pay

One of the key elements of sustainability of an electrification programme is the expected level of electricity sales, and the ability of communities to pay for the electricity service. Settlement-specific data on income levels, expenditure, and sources of income is generally not available from existing databases.[11] Generalised data such as that from the *A to Z - The Decision Makers Encyclopaedia Of The South African Consumer Market* (Eskom 1996) is combined with regional experience to estimate likely demand growth patterns. Planners undertake informal socio-economic reviews (discussions with a few members of the community) to inform their judgement regarding levels of wealth and stability in the area, and the related assessment of consumption growth. Eskom currently does not undertake formal socio-economic surveys of settlements prior making the decision whether or not to electrify a community.

Willingness to pay (used in an economic analysis) is based on regional data about pre-electrification energy consumption. While the principles and procedure for transforming energy consumption data to an equivalent 'willingness to pay' are sound, the fact that regional rather than settlement specific data is used limits the insights into settlement-specific conditions.

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[10] A review of thirty projects in 1995 indicated that all the projects had negative financial NPVs. 60% of projects had a negative economic NPV, with an approximate normal distribution of the economic NPVs around zero (Matlhare & Steyn 1995).

[11] The recent census data will provide income and expenditure data down to enumerator areas.

3.2.6 Technical criteria

Technical criteria include issues such as:

- reliability and quality of supply;
- maintenance requirements;
- design life;
- flexibility of technology for later upgrading if demand increases beyond design.

The principle area where criteria are required in grid electrification is the design capacity of the transmission lines and reticulation network, in order to cater for the expected After Diversity Maximum Demand (ADMD), and to ensure that the quality of supply is in accordance with the specified standards. The standard of supply and the ability of local networks to cope with peak demand conditions is potentially an area of significant debate that has not been adequately explored in this work. Important considerations are:

- How much can costs be reduced if the allowable voltage drop is increased? For the majority of domestic applications (lighting, TV, thermal applications), the current standard of supply is higher than necessary.
- What options are there for peak management through scheduled or unscheduled load shedding in rural communities? At what outage frequency and duration do the costs of interrupted supply become significant?[12]
- What economic and financial penalties will occur, and when will they occur, if under-design of transmission and reticulation networks takes place? Given uncertainty regarding demand growth, it may be financially efficient to design the majority of settlement schemes for relatively low ADMD. For those settlements where upgrading is required soon after electrification, the increased costs may be more than offset by cost savings in the other settlements where significant load growth does not take place.

Technical criteria and quality assurance mechanisms for off-grid systems are in a state of development, with draft standards for SHSs, and schools systems published by Eskom NRS. This area has been reviewed in some detail by Cowan et al (1996b), and is not discussed further here; suffice to say that assurances and standards regarding product quality, reliability, maintenance and performance should be closely integrated with project finance approval (see Table 8).

3.2.7 Environmental criteria

The environmental impact of grid electrification is generally not considered to be a major problem area (at the transmission and distribution end). Eskom does have a well defined environmental policy, and has on occasion gone to considerable length to minimise damage to wildlife and, in certain cases, vistas, through careful pole or routing design. In KwaZulu/Natal, (and presumably other regions) the consultants employed to carry out project planning complete an environmental checklist. This is used to avoid sacred sites and possible damage to water resources and crop resources (Van Gass 1997).

One the other hand, topographical and vegetation conditions can have a significant effect on grid extension costs, and on the costs of reticulation, although they have little influence on stand-alone off-grid installations. There are, however, significant regional differences in the renewable energy resource base, linked primarily to climatic conditions (solar radiation, wind resources, water precipitation rates), and local topographical conditions (wind, micro-hydro).

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12 Indications are that, contrary to expectation, the costs of frequent failure of domestic electricity supply are high. People frequently quote poor reliability of the grid as one of the reasons for continued multiple fuel use, with the associated requirement for multiple appliance ownership (or failure to purchase electrical appliances).

Environmental externalities which result from the generation of electricity are not considered in this report, except with reference to the economic analysis of the cost of supply in the CBA models (section 4.3).

3.2.8 Community infrastructure and facilities

The status of existing community infrastructure (clinics, schools, public facilities) is currently assessed during preliminary planning processes, and the benefits of particular school and health facility electrification are included in the Eskom/DBSA financial and economic analysis carried out for electrification projects. Nevertheless, the emphasis of the electrification programme is on the number of households connected, and the cost per connection. Thus the impact of potential community facility benefits on project prioritisation is perhaps undervalued.

On the other hand, both Eskom and the IDT have large programmes underway which specifically focus on community facilities (schools and clinics respectively). These often reach out ahead of the household grid programme, with the result that subsequent household grid electrification can take place at lower cost. Similar cost-sharing between water supply projects and household electrification also occurs. Off-grid school and/or clinic electrification is a useful indicator of the location of potential sites for off-grid household electrification. A number of potential off-grid service providers have proposed initial activity in communities that have PV school or clinic systems. The community facilities (if working properly) provide good examples of the potential of off-grid technology. Furthermore, investments by the large service providers in off-grid technology provide a strong message to householders regarding the low probability of grid electrification.

3.2.9 Integrated planning

There is acknowledgement of the need for integrated planning, consultation and a measure of co-ordination amongst different delivery agents. There is also an acknowledgement within the major implementation agencies of the need for electrification to take place where other key infrastructure is already in place, or being put in place. The practical achievement of greater synergy with development planning activities has, however, been difficult, and generally impossible to achieve for a number of reasons:

- grid electrification is frequently ahead of other infrastructure developments and planning processes;
- there is disparate responsibility for different planning functions;
- lack of information or certainty regarding existing project timing (Focaraccio & Gerstner 1997);
- delays in the establishment of infrastructure planning forums by government;
- a tendency for communities to focus on one service at a time in seeking to meet their needs (Focaraccio & Gerstner 1997).

3.2.10 Public debate and community involvement in decisions

Public debate of electrification planning and priorities has been carried out at different levels. Some regions (e.g. Northern Province, Free State) have involved electrification forums in negotiations around settlement prioritisation. Results have been mixed, with the process leading to successful prioritisation in the Free State. However, in other areas there have been times when Eskom was pressurised into the inefficient electrification of small portions of a large number of settlements in deference to the principle of inter-settlement equity.

At the community level a high demand for grid electrification is generally expressed. This is not the case for off-grid options, which are usually seen as second best. Involvement of leaders and householders in decision-making regarding the viability of grid electrification (and design and delivery options that may affect viability) are kept to a minimum. Direct engagement with community members is generally avoided, to avoid raising expectations, until such time as a decision has been made to go ahead with project implementation. While Eskom would prefer to reduce capital costs by using significantly more limited-current connections, the choice between limited-current and 20 A supply is made by householders on an individual basis, with little tariff advantage to householders who choose the limited-current option. (The limited-current option is offered with no connection fee, while a connection fee of R75 is required for the 20 A option. Most householders choose the 20 A option.)

3.2.11 Political involvement in electrification planning

The entire electrification programme can be viewed as resulting from a politically motivated 'electricity for all' base. However, officials try to avoid political influence of settlement prioritisation, or partiality to particular groups. Some Eskom projects, for example, cover settlements aligned to different political groups within the same project. This author was not able to assess how effective planning officials are in maintaining non-political objectivity. In some areas significant (sometimes forceful) local pressure from communities has been evident. In some other cases there has been high-level intervention by politicians to influence electrification plans to achieve electrification of specific communities (Bopela 1997).

4. Information and analysis to support decision making

4.1 Databases and GIS

Information resources, particularly in the form of GIS / databases, which can assist electrification planning are currently being reviewed by Trollip (1998, in preparation). Major databases of interest include the HELP database, the NELF/NER database, and the IDT database.

For most rural areas information is available on the following:

- settlement size (number of households);
- settlement area (which, together with the above, can be used to estimate the number of connections per km^2);
- settlement shape (not available for all areas);
- location of schools and clinics;
- status of electrification in the area;
- some indication of water supply status;
- road infrastructure.

Settlement-specific demographic information (household size, population structure) is not as readily available, although by mid-1998 it should be possible to link the recent national census data to 'enumerator areas'. This will improve general availability of demographic data. Settlement-specific information on income, expenditure, source of income, or other wealth-related indices is generally not readily available, and is often collected for specific tasks. Again, the release of the census data is expected to improve matters significantly. Information regarding the number and scale of informal and formal business activity in rural unelectrified communities is generally not available.

Very few settlements have been surveyed in order to determine energy consumption patterns and trends, so that settlement-specific data would have to be collected if required. There is, however, a considerable body of information on energy consumption in different regions of the country, which can be used as a first-pass indicator of energy consumption in target settlements. It should, however, be noted that there can be significant variation in energy consumption patterns within settlements that are in close proximity to one another.

4.2 What do planners need to know?

The following table presents a list of information which it would be useful to know before electrification decisions are made, together with brief comments on the factors. Also listed is an indication of whether the factor is likely to be adequately accounted for in the consumer financial analysis (CFA), the project or utility financial analysis (FA) or a project economic analysis (EA), or whether the factor requires additional assessment (perhaps qualitative rather than quantitative) (Oth). A single tick (✓) implies that the factor will affect the analysis, but that it is not fully reflected. Three ticks (✓✓✓) imply that the factor is well reflected in the analysis.

Table 5: Factors which should be considered in electrification decisions

	Characteristic	*Comment*	*Oth*	*CFA*	*FA*	*EA*
1	**Financial and economic indicators**					
1.1	Estimated capital cost per household connection for proposed energy supply option(s).	Directly affects financial and economic viability. (For indicators of capex see section 2.3.3 and Annexure A)		?	✓✓✓	✓✓✓
1.2	Financial NPV on a per household basis	Indicates the financial return (or subsidy required) per household.			✓✓✓	
1.3	Financial NPV of entire project	Indicates financial return (or subsidy required) for project as a whole.			✓✓✓	
1.4	Economic NPV on a per household basis	Indicates the economic return (or cost) per household.			✓✓✓	
1.5	Economic NPV of entire project	Indicates economic return (or cost) for project as a whole.				✓✓✓
1.6	Financial internal rate of return (FIRR).	Indicates the financial discount rate at which the NPV is zero.			✓✓✓	
1.7	Economic internal rate of return (EIRR).	Indicates the social discount rate at which the economic benefits balance the costs.				✓✓✓
2	**Consumption growth potential**					
2.1	Expected hh electricity consumption for the given technical option	The higher the better for grid. Should be based on regional historic data, modified using socio-economic/income indicators. For off-grid, will hh be left frustrated by too low energy availability?		✓	✓✓✓	✓✓✓
2.2	Has demand for the service offered been quantified?	(No of applications, deposits paid?). It is difficult to assess real demand without some measure of commitment from people	✓	✓	✓	✓
2.3	Is expected hh demand and associated tariff realistic for a cross section of hh?	Will require some assessment of wealth, income levels, income sources and or energy expenditure.	✓	✓		
2.6	Are cooking needs a priority for change for hh?	If so, stronger motivation for grid, or in case of off-grid for gas or alternative fuel strategy in parallel	✓	✓	✓	✓
2.7	Are biomass resources scarce	Low biomass resources may indicate high priority for thermal energy services	✓			?
2.8	What percentage of household purchase woodfuel rather than collecting it?	Greater commercialisation of woodfuel supply can indicate low availability as well as a greater willingness to pay for energy	✓			✓
2.9	What is the proportion of households in which women have sufficient economic power to influence appliance and energy purchase decisions?	This may increase rate of cooking appliance purchase, and hence grid electricity demand	✓	?	?	?
2.10	Are space heating needs a priority for hh (location, climate)?	If so, what implications for ADMD (grid), or parallel initiatives for off-grid			?	?
2.11	Have constraints to electricity use been identified and steps taken to alleviate these where possible?	Eg: financing for appliances?	✓	✓	?	?
2.12	Willingness to pay	Has this been estimated/assessed on a settlement specific basis, or are average figures used? What about differences within the settlement?				✓✓

	Characteristic	Comment	Oth	CFA	FA	EA
3	**Community empowerment and involvement**					
3.1	Level of organisation in community	Increased levels of organisation will facilitate certain approaches to service delivery	✓			
3.2	What use of community or local contractors in project implementation?	Helps to achieve RDP goals and enhance local economic benefits.	✓			✓
3.3	What are the levels of job creation through use of community members in longer term project operation (vendors of electricity, maintenance of SHS)?	Helping to meet local empowerment objectives. May also indicate better chance of sustainability, esp. for off-grid.	✓			✓
4	**Status of settlement and existence and condition of public facilities**					
4.1	Size of settlement	Larger settlements (relative to others in the vicinity) are like to be more important, have a lower cost per connection			✓✓	✓✓
4.2	Condition, size, no of people served by health facility	Indicator of need for electricity (and hence social and economic value)	✓			✓
4.3	Will health facility and service be improved as direct result of electrification project?	Will bring increased revenue as well as other benefits: willingness to pay, externalities	✓		✓	✓
4.4	Condition of school	If school in very poor condition, will electrification of school be wise use of resources?	✓			✓
4.5	Size and type of school (primary or secondary)	Indicator of need for electricity supply Should be included in 'willingness to pay' to be incorporated.	✓			✓
4.6	Water supply: Is it adequate or will it be upgraded in near future?	Adequate water necessary for stability/development of community,	✓			
4.7	Will electrification project contribute to water supply upgrade?	Contribution of electricity to water supply can be well quantified			✓✓	✓✓
4.8	Is the community easily accessed by road?	Greater access to road allows greater economic potential, and also facilitates operation as dormitory for other income activities in larger centres	✓		?	?

	Characteristic	Comment	Oth	CFA	FA	EA
5	**Potential for economic development and non domestic demand**					
5.1	How many businesses are there in the settlement?	This information should probably be broken up into different classes of business	✓		✓✓	✓✓✓
5.2	Have the requirements of larger consumers been quantified and included in analysis?	High load users can significantly improve viability of grid options	✓		✓✓	✓✓✓
5.3	What is the potential for productive enterprise development and job creation?	Difficult to assess- but some attempt should be made	✓		?	✓
5.4	Can direct or indirect benefits of electrification of businesses be quantified?	Indirect benefits could lead to higher domestic or secondary demand elsewhere	✓			✓
5.5	What is the agricultural potential?	Arable land per capita, water availability, market availability	✓			✓
5.6	Can the direct benefits of electrification for agriculture be quantified?	Water pumping, processing	✓			✓✓
6	**The overall energy picture**					
6.1	Has integrated energy planning been carried out?	If integrated activities take place, this can enhance benefits, particularly for off-grid. Also allows better exploration of alternatives. If project includes thermal services, is much easier to compare with grid.	✓		✓	✓
6.2	Have opportunities for other energy services which could have synergistic benefits for the project been explored and plans for development been formulated?	For example, off-grid project viability could be enhanced through provision of gas or other thermal energy service.	✓	?	?	?
7	**Development planning and development initiatives**					
7.1	Is integrated development planning taking place in the region, and is this project part of that process?	Efficiency, and benefits of various service and infrastructure delivery can be improved	✓			✓?
7.2	Is broader development activity ongoing or planned in the region?	Indicator of potential increase in economic activity, and hence viability of electrification project	✓			✓?
7.3	Are there specific initiatives taking place which will increase opportunities for economic development?	Eg: SMME support, adult education, development of nearby labour market	✓			✓?
7.4	Are there indications that the community is likely to remain in the area?	Many of the above questions related to this. Other factors which could be assessed include: migration patterns, house structural types, assessment of regional developments which may draw people away, land redistribution developments	✓			
8	Other					
8.1	Are there unusual circumstances which would affect the analysis of externalities?	Eg: Severe biomass denudation, unusually high rate of respiratory disease	✓			✓

Full attention to the elements of **Table 5** would require:

- detailed information on each of the settlements being considered;
- better knowledge of the indicators of future consumption than we have at present (see section 4.3.2.2);
- development of a methodology to allow reasoned valuation and integration of the less readily quantified elements of the above table into the evaluation process;
- historically based validation (or otherwise) of assumptions used.

The right hand columns of **Table 5** indicate that the financial analysis and the economic analysis are influenced by, and attempt to take into account, most of the important issues. A financial analysis and, to a greater extent, an economic analysis gather together and process a large body of information, and produce a reduced set of reasonably well understood indicators which can be used to guide decisions. Of course, if abused, or based on incorrect information, the economic and financial analysis can lead to poor decision-making. Given their importance to the electrification decision-making process, these analysis tools are discussed in more detail below, with some examples of how they can be used as a guide to electrification decisions.

4.3 Financial and economic analysis as decision tools

4.3.1 Introductory notes

Financial and economic analysis of projects are likely to be the dominant tool to assist in electrification decisions. These can be used in different ways, and the most appropriate use depends to a large degree on who is making the decisions, and what their objectives are.

A financial analysis from the utility's perspective should consider all costs and expected revenues associated with a project. The results can effectively be presented in the form of a net present value (NPV) for a realistic project life – typically 15 to 20 years. If the inputs to the model do *not* include any subsidy, then the model will indicate the return on capital to be expected, or if the NPV is less than zero, this will indicate the subsidy required to sustain the project. On the other hand, if currently applicable subsidies are incorporated in the tariffs and costs used, the analysis reflects the utility or investor's financial perspective under prevailing conditions.

An economic analysis of projects considers the costs and benefits of a project from a national point of view. This involves modification of the financial analysis through the removal of any taxes and subsidies. Imported equipment is normally priced using a shadow exchange rate, and labour components using a shadow wage rate.[13] Prices paid by users are replaced by an estimation of the user's willingness to pay. This tries to value the benefit to a consumer of electricity, not only in terms of reduced expenditure on other fuels, but also in terms of the added benefit that electricity consumption will bring. Further costs and benefits which would result from a particular technology choice that are external to the immediate project cash flows should also be included. These include health benefits associated with decreased exposure to particulates, the lower risk of fires and burns, environmental benefits such as reduced woodland denudation, and the value of time savings which may result from changes in fuel usage patterns. An economic analysis should also include the multiplier effects of electrification, including the impacts on small enterprises. However, as Davis (1997) notes, many of these factors are difficult to quantify and, although their effect may be real, it is hard to justify their reliable use in decision-making processes without substantive quantification of impacts.

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13 Davis (1997) notes that, due to rapid changes in South Africa's economy, existing data on shadow rates is outdated, and thus financial costs should be used.

While there is a lack of clarity regarding national electrification policy it is difficult to make firm recommendations regarding the weighting that should be given to a financial analysis, economic analysis, or social benefits analysis in prioritising electrification decisions. A number of illustrative options are listed below which may help to clarify thinking.

Option 1: The National Electricity Fund (NEF) will allocate resources seeking to maximise the number of connections to be achieved using a financially constrained electrification fund. In this case a financial analysis should be prepared by the project applicants. This should indicate the minimum subsidy required to make the project financially viable to the project applicants (presumably the utility). The NEF would then rank projects according to the *subsidy required per connection*.[14]

Option 2: The NEF will allocate resources, seeking to maximise the return to the national economy on national resources invested. In this case the projects should be ranked according to an *economic analysis* (EIRR, Economic NPV or CBA). The NEF would have to allocate subsidies to the service provider to make the project financially viable. The amount of subsidy required would be determined by the financial analysis.

Option 3: The NEF will allocate fixed subsidies to electrification projects based on the number of connections[15] to be achieved in the projects. In this case the other investors (presumably the utility) would prioritise projects based on the *financial return on investment* to be expected given the predetermined subsidy. This will lead to a similar ranking order to that described in Option 1. It is intuitively more fair, however, in that flat-rate national subsidies could be used. It would also have significantly lower auditing requirements than either Options 1 or 2, as the accuracy of the financial analysis would not affect the amount of subsidy allocated.

Option 4: Projects could be screened according to certain criteria (for example, that the subsidy per connection to achieve financial viability is less than RX). They can then be prioritised according to a range of weighted social, economic and other indicators such as those listed in section 4.5.1 This may allow one to dispense with the relatively complicated economic analysis in the decision-making process. In this case either a variable subsidy (ranging from 0 to RX), or a fixed subsidy equal to RX would be required.

From the point of view of equity, Options 1 or 3 are likely to achieve the maximum number of electrification connections, given limited electrification resources. Option 2, may achieve fewer connections, but would hopefully maximise the economic returns on resources invested for the country as a whole. It seems that neither approach is ideal. Option 4 would allow less easily quantified variables to be incorporated in the primary ranking process. As discussed below, however, these factors should be considered in *any* ranking process, in the other options they would however be secondary influences on rank, rather than being numerically incorporated as in Option 4.

There is another perspective, that of the consumer. A financial analysis from this perspective takes into account only those costs and benefits which will accrue to the consumer (householder, education department, health authority, water supply authority). This is an important part of project decision-making for two reasons. Firstly, it can be used to provide information to prospective customers to assist them in making decisions regarding technology choice, or funding commitments. Secondly, the end user analysis, with its focus on the household-level exchanges, can assist in the process of assessing take up rates for a given technology, and in the case of grid connections, in assessing the expected load that will be drawn. This analysis is very important in assessing whether a particular energy intervention is

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14 If operating costs and revenues do not vary significantly between projects, consideration of capital costs only will approximate this scenario. Eskom's current rural electrification criteria approach this.

15 For example, the NEF could provide R2000 per 20 A connection, R1750 per 2.5 A connection, R1500 per 50 W_{pk} SHS system, R40 000 per school, R 50 000 per clinic.

likely to be feasible from the end users point of view. It also provides important input material for project level financial or economic analysis.

4.3.2 Information requirements

A financial or economic analysis can only be as good as the information on which the analysis is based. Furthermore, since the decisions at hand tend to involve entire communities, the analysis needs to cover the full spectrum of consumers and energy uses and costs. The information inputs are all listed in Table 5 (those with a mark in the appropriate column). Financial and economic analyses of electrification projects show considerable sensitivity to a number of key variables, including:

- load and load growth;
- cost of generation;
- tariffs (especially in the case of non-grid, where these have not been properly defined yet);
- willingness to pay;
- load factor (for bulk supply costs of grid electrification);
- technical and non-technical losses;
- capital costs – again an area of uncertainty at present for off-grid solutions.

While such data is unreliable, and sometimes inherently uncertain (load growth, non-technical losses) the results of the analyses have to be treated circumspectly. There is, however, considerable experience to date of grid electrification, and it is essential that historical data be used to determine with greater certainty factors such as load and load growth, load factor, technical and non-technical losses.

Capital cost, expected consumption, and 'willingness to pay' are further discussed below.

4.3.2.1 Capital costs per connection

The information required to roughly assess capital costs of grid electrification projects is readily available. As noted in section 2.3.3 of Annexure B, the principal indicators of expected capital cost are settlement density, settlement size, length of grid extension required to reach settlement, and topography. Two factors which are not as easily dealt with are cost-sharing of bulk infrastructure between different electrification projects, and determination of the design ADMD. In some cases, where houses are scattered in small clusters, density is not a useful parameter, and Stephen (1997) has suggested the use of 'connections per kilometre of MV line' as the most appropriate basis for cost estimates. Broad indicators could be used for first-pass decision-making. However, if economic or financial analyses of specific settlements are required, then more accurate cost information should be obtained.

The cost of obtaining reasonably accurate cost estimates for grid reticulation need not be very high. Firstly, there is considerable experience in South Africa of rural electrification project design and management, so that past experience (and data from completed projects) can inform new project assessment. Secondly, software exists that allows engineers to make rapid preliminary selection of technology using little more information than can be read from a 1:50 000 map and data on settlement boundaries and the number of households. Similarly, for bulk electricity supply, preliminary design work is relatively cost-effective to carry out. Thus, where there is uncertainty regarding electrification decisions it is recommended that preliminary network and reticulation network cost exercises be carried out before decisions are made regarding electrification prioritisation or off-grid/grid technology choice. Certainly, by the stage financial or economic analysis of a project is carried out, reliable cost estimates should be available.

In the case of off-grid electrification, determination of capital costs will require a good understanding of the expected loads in the settlement. This will require engagement with potential customers, and analysis of their needs. Furthermore, the renewable energy resource base will have to be assessed. Costs for particular levels of supply are however fairly easy to determine (given appropriate design tools and access to current pricing information). Thus, for specified load capabilities, reasonably accurate information on capital costs can be fed into the decision making process. However, where final demand is uncertain, the capital costs of renewable systems will be more susceptible to change than those for grid (See section 2.3.3).

In summary, assessment and presentation of expected capital costs is not expected to present difficulties in the project evaluation process.

4.3.2.2 Expected electricity consumption

There are significant variations in domestic electricity consumption in different settlements. Davis (1995), in a review of electrification consumption in the Eastern Cape, Mpumalanga, North West and Northern Province, and KwaZulu-Natal noted a significant spread in average settlement consumption, even for settlements that had been electrified for more than two and a half years. There was also considerable scatter in the consumption growth rates, with negative consumption growth rates being recorded in some cases. Average household consumption ranged from a low of less than 20 kWh/month upwards, with very few settlements having an average consumption over 150 kWh/month. Figure 3, which shows the average consumption for 108 settlements in the Northern region illustrates the variance graphically.

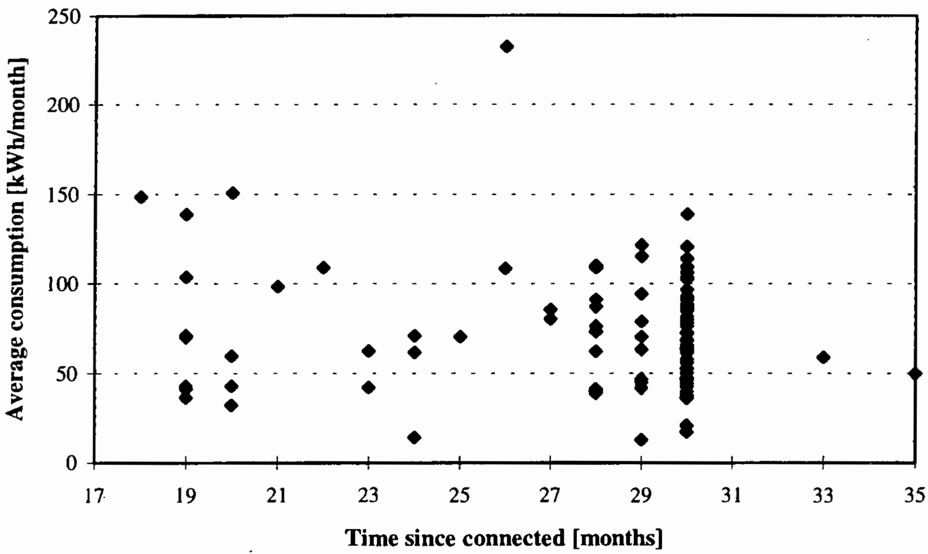

Figure 3: Average consumption against time since connected – Pretoria region
Source: Davis 1995)

In the same report, Davis illustrates the effect of consumption (kWh/customer/month) on the effective monthly subsidy (or cross-subsidy) required per customer. For the assumptions used[16] the required subsidy required changes in a reasonably linear fashion. R38 per customer per month is required at a consumption of 50 kWh/customer/month, R21 per customer per month at a consumption of 200 kWh/customer/month, with no subsidy required if the average consumption is 400 kWh/customer/month. Economic and financial NPV's show similar sensitivity to the consumption, and consumption growth rate.

The variations in domestic consumption, and the importance of domestic consumption to the financial and economic costs and benefits of electrification indicate that predictions of domestic demand should play an important role in electrification project prioritisation. The use of national or regional averages (as is

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16 Capital cost of R3000 per connection, support costs of R25, bulk supply costs based on marginal costs and tariff changes in line with Eskom's pricing compact, a real discount rate of 6%.

usually the case) will significantly limit the utility of the financial or economic analysis as a prioritisation tool.

Unfortunately, indicators of likely consumption have not yet been adequately determined in the research reviewed. Although both Dekenah (1997) and Davis (1995) indicate that income and income-related variables are important, both acknowledge that there may be other variables of significant importance. Neither quantify the relationships. James (1997), reporting on a study carried out in Tambo village, indicates that a direct linkage of consumption to income is 'hopelessly over-simple and inadequate'.

Uncertainty regarding indicators of future consumption places the analyst or planner in a somewhat difficult position. Clearly, this is an area requiring further research. Such research is now eminently possible, given the significant number of electrification projects that have already been carried out in different regions of South Africa. It should be possible, through analysis of historical consumption data, and identifiable socio-economic indicators such as apparent wealth, sources of income (including whether this is earned by male or female household members), levels of education, household construction type, household power structures, education levels, source of income, etc. to at least improve the current approach. [17]

Even if income-related indicators are the most useful indicators of potential consumption, there are significant difficulties in accessing settlement specific data for these variables. Data sources such as the most recent census may prove useful in this regard. Furthermore, sub-regional experience (enhanced through detailed analysis of sample communities and reference to historical consumption trends in the sub regions) should be explicitly built into the analysis process.

For the present, even though their utility has been questioned, it is recommended that wealth related indicators will provide the most useful indication of demand, and these are therefore used in the criteria listed below.

4.3.2.3 Willingness to pay

Assessments of 'willingness to pay' provide an input to the economic model which gives an indication of the value of the service being offered to the customer. In grid electrification projects, this will usually be higher that the tariff rate. Davis and Horvei (1995) discuss this in some detail. Suffice to say here that:

- Domestic 'willingness to pay' requires information of different consumer categories, and their pre-electrification energy consumption. It has been argued that regional average figures should be used. This does not take into account differences in energy consumption between different settlements (or between different groups of domestic consumers within settlements). If greater attention is to be paid to differentiation between settlements, then socio-economic and energy information on settlements will be required and should be utilised in calculating the willingness to pay. (The Eskom/DBSA model does have provision for this sort of data input).
- The 'willingness to pay' for businesses will usually be significantly higher than for domestic customers. Similarly, the 'willingness to pay' for school and clinic systems is usually taken as being equivalent to the cost of a PV system (least cost alternative to grid, given that there is a decision to electrify all clinics and schools).

4.3.2.4 Discrimination between different settlements

Current electrification planning processes do not involve socio-economic surveys of settlements to gather data to assist prioritisation and planning. Existing data sources, and very limited discussions with community members are used as the

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[17] The ongoing NRS National Load Research Project and parallel Eskom TRI work (which has sample settlements in rural areas (Lawrence 1997)) should contribute significantly to the identification of appropriate parameters and relationships.

information source. Frequently, national or regional averages are used for important inputs such as expected consumption and consumption growth rate and willingness to pay. Such average figures are useful in that they give a picture which is broadly representative of the country (or large regions), and they can also be useful in assisting generalised technology recommendations (see section 4.4.2). However, if these tools are to be used to distinguish costs and benefits for different settlements (and thereby assist in prioritisation) more detailed information will be required. It is necessary to use sub-regionally-specific (and preferably settlement) data for important factors such as demand and load growth (see above), willingness to pay, operational costs and business development. It is important that these figures be checked, and that the considerable electrification experience gained to date be analysed and used to enhance the accuracy of predictions for proposed projects.

4.4 Examples of the use of financial and economic analysis to inform technology choice

Economic and financial analyses have not been applied to a significant number of case studies of settlements using grid and/or off grid electrification. Most comparisons are carried out for particular categories of end use application: domestic, clinic, school or water pumping. Furthermore, project based experience of off-grid settlement electrification is essential before generalised rules regarding indicators of economic or financial viability for given technologies can be developed. There is simply too much uncertainty regarding off-grid system performance, acceptance and benefits in rural communities. Some issues and results from work that has been carried out are highlighted below.

4.4.1 Financial analysis from the consumer perspective

Financial analyses of different technology options from the household consumers perspective have been carried out by a number of researchers, using assumptions regarding tariffs (Davis 1997; Hochmuth & Seeling-Hochmuth 1997). These attempt to quantify the monthly savings or changes in energy consumption and expenditure that will occur as a result of a technology choice, and to quantify the resultant expenditure that a household would incur. As such they require that demand assessments be carried out, and indeed may help to predict likely demand where information is uncertain.

If standard tariffs are used then, from a customer's viewpoint, the prepayment meter option is likely to be strongly preferred. For example if a householder uses two 60 W light bulbs and a colour TV rated at 80 W for four hours per night, the monthly cost at a prepayment meter tariff of 28.18 c/kWh would only be R7. This is less than the usual expenditure on torch batteries and candles for lighting. A standard SHS system may provide sufficient energy for, say, three lights for four per night, and a TV. However lighting levels would be lower and the TV would normally have to be monochrome, as colour TVs require significantly more energy. It is hard to imagine a realistic SHS tariff below R15 per month. A SHS system with an installed cost of R3500, a R1500 subsidy, a deposit of R200 would require monthly payments of R52 over a 48 month period at a 17.75% interest rate, excluding the cost of battery replacements. Proposed payment rates for SHS for an Eskom pilot project are of the order of R40 per month (for a three-year period). A limited current supply tariff of R7 also seems unrealistically low.[18] A limited-current supply is unlikely to deliver significantly greater end use benefits to the consumer than those described in the above scenario.

Thus, at current tariff rates, the end user analysis does not significantly help the process of technology selection; indeed it tends to bias users strongly towards 20 A grid connections. If connection fees and tariffs were adjusted such that they

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18 Although the flat-rate tariff was initially set at R8.50/month in Mafefe, this was subsequently increased to R15/month – with a resultant increase in default rates (James 1997).

indicated to the customer the real costs of grid connection (as they currently do for off-grid systems), then end user financial analysis would become a more useful tool.

Where grid is definitely not an option, the users financial analysis will help to indicate the preferred option from a range of different off-grid technology choices (solar lanterns, battery charging systems, and different sizes of SHS) – again the analysis will be significantly affected by the tariff levels. For an example of an analysis which compares different off-grid technologies for household lighting and communications, see Hochmuth (1997a). **Figure 4** below is reproduced from Hochmuth's report, and indicates the importance of assessing customer energy demand, as the most viable technology for a particular customer will depend on the expected consumption level. Hochmuth's analysis assumes that no subsidy will be made to the end user (provided that the capital and operating cost of the battery charging station will be recovered through the fee for battery charging). Thus the NPV gives a reasonable indication of the best technology option for the customer.

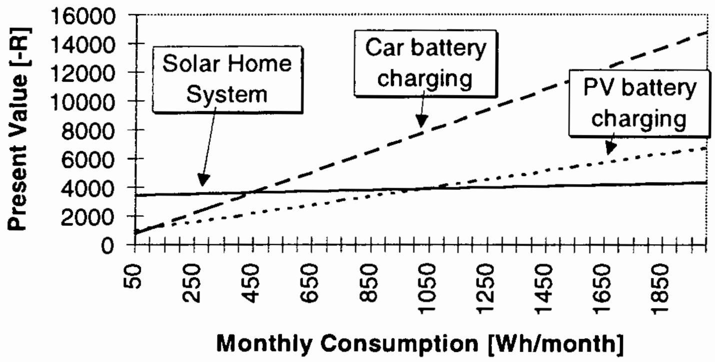

Figure 4: Net present value (negative) to the customer of three different off-grid technologies for lighting and TV or radio, vs. monthly consumption
Source: Hochmuth (1997a)[19]

The end user analysis, with its focus on the household level exchanges, can assist in the process of assessing take-up rates for a given technology and, in the case of grid connections, in assessing the expected load that will be drawn. This analysis is very important in assessing whether a particular energy intervention is likely to be feasible from the end users point of view. It also provides important input material for project financial or economic analysis.

Where the end users are larger customers such as community services (water supply, education department) or business, then the end user analysis will provide a more useful indicator of technology preference if the tariffs charged to the customer reflect the real costs of service delivery. In present electrification practice, this is sometimes the case, as Eskom charges funding agencies (IDT) or the appropriate departments (DWAF, DOH) for line extension costs.

4.4.2 Financial and economic analysis applied to a community as a whole

4.4.2.1 The Mafefe and Tambo case studies

Davis (1997) reports the results of an economic and financial analysis of two recently electrified settlements, Mafefe and Tambo. Three technical options were compared: solar home systems, grid connections limited to 2.5 A, and 20A prepayment meter connections. This work is particularly instructive to the development of electrification decision criteria for the following reasons:

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[19] Hochmuth's analysis included a number of assumptions regarding costs for capital and O&M that are as yet hardly tested (a difficulty for all off-grid technology comparisons at present). The above curves are thus presented for illustrative purposes only and should not be used for decision making.

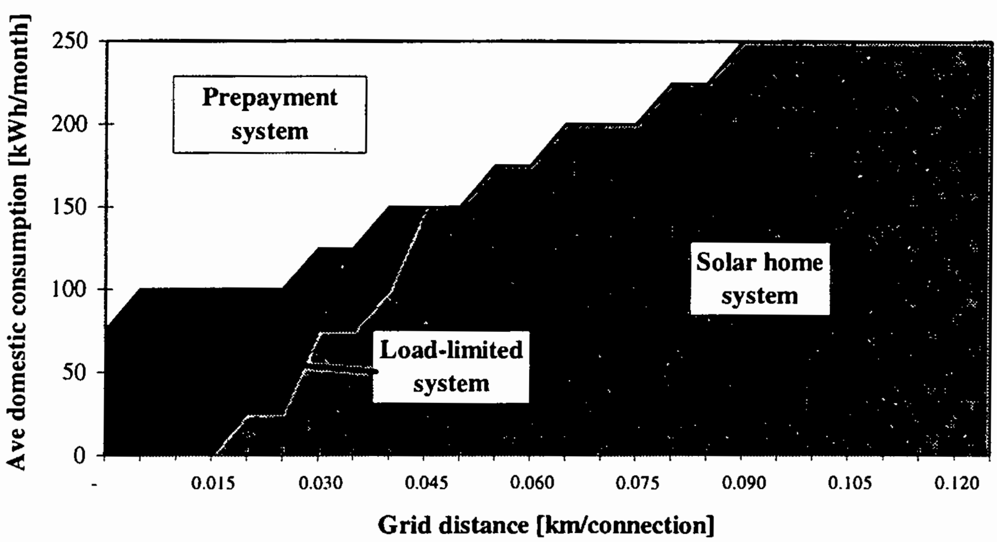
1. The economic analysis was extended to include health- and environment-related externalities related to electricity generation on the one hand, and, more importantly, substantial positive primary health and safety benefits resulting from the provision of grid.
2. Davis explicitly included non-domestic customers such as schools, clinics, and small businesses in the analysis.
3. The study explored the effects of consumption levels and grid extension distance (equivalent to a focus on the capital cost per connection) on the economic and financial performance of the projects.

Although the analysis indicated that for all technologies substantial subsidies would be required (financial NPV per customer ranging from negative R2200 to negative R4100), the economic results were more encouraging, with positive net present values for the grid connections, but still a negative Economic NPV for solar electrification.

With regard to technology choice Davis summarises:

> The analysis of the conditions under which each supply technology is optimal has shown that load-limited supplies are preferred, from the utility's perspective, at consumption levels of less than 150 kWh/month per customer and relatively short distances from the grid. For consumption levels higher than this, prepayment systems generate fewer losses. At low consumption levels (less than 50 kWh/ month), off-grid supplies are optimal for even very short distances from the grid (as little as 20 m per connection[20]). Where consumption is higher, off-grid systems only become financially attractive to the utility in the case of communities which are further from the grid. If the same analysis is performed from an economic perspective, then it is apparent that prepayment metered supplies are optimal over a much greater consumption and distance range, that the niche for load-limited systems is restricted to lower consumption levels, and off-grid systems are optimal at only much greater distances from the grid

The following figure illustrates the financial results graphically:



Note: Multiply grid distance by 690 to get actual distance for Mafefe

Figure 5: Optimum supply from a financial perspective (using Mafefe data)
Source: Davis (1997)

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[20] This refers to the distance of the settlement from the closest grid line, divided by the number of households in that settlement.

Hochmuth and Seeling-Hochmuth (1997) present in-principle financial analyses for battery charging systems, PV solar home systems, hybrid systems, and mini-grids. These raise some of the important considerations in estimating costs of using different technologies. The authors suggest that decision charts could be prepared, to act as a guide to decision-makers, based on parameters such as average demand per connection and density of connections. However, they also acknowledge that costs are sensitive to specific load in settlements, proximity of high loads to each other (important for a mini-grid evaluation), and renewable and non-renewable resource availability.

It would be attractive to draw up charts based on the results of generic financial analyses to support decision-making based on generalised financial analyses (as suggested by Hochmuth and Seeling-Hochmuth). Similarly, a financial and/or economic analysis of the type described by Davis could be used to generate generic decision guide charts. These would enable one to use gross indicators such as distance from grid, proximity of households to each other, and expected load for decision making. Considerable care should however be taken, and it would be premature to use such methods extensively before we have greater experience of the actual costs of different electrification options, and a greater understanding of the sensitivity of costs to different circumstances. The main areas of concern are:

- Variations in capital costs for both grid and off-grid systems. The range of estimates for the capital costs of off-grid systems in particular is still considerable, with prices from R1500 to R3400 being given. (Davis used a high installed cost of R3 400 per system).
- Lack of clarity at this stage regarding tariffs and payment methods for off-grid technologies.
- The need to include settlement specific data on non-domestic loads, and on expected consumption in the decision process. As Davis (1997) illustrates, these can have a significant effect on the analysis results.

Part of the value of the financial and economic analysis, is that it allows a number of important settlement specific variables and data to be combined together and analysed in a formalised manner. Spreadsheet-based models for analysis of grid projects have been developed, and it would not require undue additional work to add components for off-grid evaluation. Thus, at relatively low cost, financial and economic analysis could be developed and used as routine tools in electrification decisions. As will be discussed in section 5.6, these tools should be actively used on a settlement-by-settlement (or project-by-project) basis, for prioritisation and to assist in technology choice.

4.4.3 Limitations of the financial and economic analysis as an aid to technology selection

Although the economic analysis attempts to include the majority of quantifiable costs and benefits associated with electrification projects, there are some positive and negative effects of grid or off-grid electrification which are normally left out, usually because insufficient information is available to quantify costs and benefits, or because the costs or benefits are not readily quantifiable in monetary terms. It is recommended that such factors be explicitly considered in a technology selection process. See section 5.6.1 for a discussion of how these factors can be included in the process of ranking grid electrification projects. Similar methods could be used for technology evaluations.

4.5 Other approaches to project identification

4.5.1 Using socio-economic indexes

A number of indicators derived from village survey data could be utilised to rank settlements directly, according to a formalised scoring system (usually not in currency units). These indicators can include elements that could usually be included in an economic analysis, as well as indicators that are not readily expressed in currency terms. For example, the provincial Electrification Authority in Thailand (Tuntivate & Barnes, 1996) utilised seven factors derived from a village survey to prioritise settlements for electrification.

- Village proximity to distribution network or other electrified villages and to good roads: This factor is akin to the above noted emphasis on capital costs. Proximity to good roads also has a bearing on development potential.
- Village size: Assessed for its impact on potential number of customers and hence distribution cost, as well as the association of larger settlements with relative importance.
- Number of initial consumers: The Thailand programme did not involve near-blanket coverage, unlike South African grid projects. Thus the number of customers at the initial stages of the project has significant effects in the early years of the project.
- Villages were assessed for the rural industry load potential. Many villages already had rice mills, power tools and water pumping equipment. This indicator served not only as an indication of significant load potential, but also as an indicator of potential for increase in income to the population
- The number of commercial establishments was regarded as an indicator of relative importance of the village, as well as an indication of initial, and sustained higher demand connections.
- The number of public infrastructure facilities located in villages was also used-partly as an indicator of relative importance of the villages, and also because supply of electricity to these facilities was believed to enhance their impact.

The above factors were given equal weighting, presumably through the use of a normalised scoring system for each, and simple addition to arrive at a single value for each settlement. Note that the above factors do not require significant analysis, and no detailed financial or economic analysis was carried out.

4.5.2 Identifying areas of potential growth and development

Horvei and Dahl (no date) review the project selection criteria proposed in a report from the Zimbabwe Ministry of Energy and Water Resources in 1991. This notes that "the criteria for project choice are to be primarily economic and social, with financial consideration being secondary". Growth potential is ranked according to:

> *location* (whether hinterland is productive, whether centre is sufficiently far from alternative urban foci to develop autonomous economic and social functions), *infrastructure* (services complementary to electricity, particularly water, roads and telecommunications) and *institutions* (such as whether title deeds are permitted and can be obtained and used as collateral for bank loans).

The hierarchy of project choice is listed in the table below.

Table 6 Heirarchy of project choice

Priority	Area poised for growth?	Economic viability of project	Financial viability of project
Highest priority -Power utility should implement	Yes	Yes	Yes
High priority- external (govt. or donor) funds required.	Yes	Yes	No
Only implement if resources available	No	Yes	Yes
Lower priority, although if communities or institutions involved can make substantial contribution accord a higher priority	Limited	Yes	No
Do not implement	Limited	No	No

5. Suggestions for a 'best practice' set of criteria

The intention of this part of the paper is to put forward a first attempt at a 'best practice' set of criteria for use at the operational level in electrification project planning. The key questions tackled are thus:

- What technology is most appropriate for electrification of different settlements in a region of interest?
- What conditions should either grid or off-grid projects satisfy before major project expenditure can be approved?
- How should electrification projects be prioritised relative to each other?

5.1 Key principles

Before discussing criteria in detail, it is useful to establish some principles which have been adopted here.

5.1.1 Objectives of the electrification programme

As noted elsewhere, a clearly articulated electrification policy has not yet been developed or announced. It is thus impossible to give proper definitions to weighting, and prioritisation of the criteria and approaches discussed below. The criteria and processes have been presented in such a way that they will support electrification policy development. At key points, options are presented, and resolution of options will depend on the electrification policy adopted. However, there are underlying policy assumptions that run through the work presented here, and these are articulated below:

Electrification is seen as a worthwhile endeavour, which aims to provide at least a minimum level of services to permanent households and communities in a sustainable manner, using resources in an economically efficient manner.

- By 'minimum level of service' is meant that households should be able to use electric lights for a few hours in the evening, and operate low power entertainment and communications devices. Community facilities such as clinics, and schools should have access to the minimum electrical energy required for daily operation and communication.
- By 'sustainable' is meant that reasonable assurance can be provided of long-term continued availability of the service, supported by revenues and, where necessary, through defined and assured alternative resources (typically cross-subsidies).

Electrification activities should seek to maximise the benefits achievable, through supply of a higher level of service than the minimum level noted above, where this can be economically justified and where the extra financial cost (if any) can be managed and will not jeopardise the electrification programme or the industry.

The social and economic benefits of both the electrification process and the subsequent service delivery should be maximised through appropriate project design and management, involvement of community members, and through active identification and development of economically viable opportunities.

Situations where provision of electricity will facilitate broader economic development should be actively identified and developed.

5.1.2 A defined resource base

Figure 2 illustrates the relationship between the operational level planning considered here, and the strategic resource allocation processes which are assumed to take place at a national level (as discussed by Thom (1998)). The principal result of such strategic planning would be the development of a multi-year budget for sub-regions. The planning methods and criteria discussed in the following sections are intended to assist decisions at the operational level, given a defined resource allocation for the sub-region.[21] It is important for results and lessons from the operational electrification process to be fed back to the strategic-level resource allocation processes.

Competition for resources with other infrastructure development projects is not addressed here. This issue should be further explored in subsequent work, as the assumption, although practical, is not necessarily valid.

5.1.3 Planning regions are small

Where there is competition between different settlements for resources, it is assumed that the planning region is sufficiently small for arguments of geographical or inter-regional equity to not apply – that is, the 'best' projects according to the criteria would be prioritised. Geographical equity considerations would be taken care of by the higher-level resource allocation referred to above. The optimum size of these planning regions has not been determined in this project, and it would certainly vary from region to region.

5.1.4 A programmatic planning process will be used

While it is possible for electrification planning to take place on an individual project-by-project basis, it is assumed that the criteria and planning approaches discussed below would primarily be used as part of sub-regional, or even regional planning processes. This may be complicated by different, independent funds being made available for electrification. The principal assumption is that decisions would be made according to an agreed process with an agreed set of criteria being used to support decision-making. This, of course, implies co-operation between different principal electrification funders.

5.1.5 Multi-pass planning

Planning will be accomplished in a number of passes, with different levels of information (and hence reliability of analysis) being available at each pass. In a first-pass planning exercise based on generally available information, particular settlements or sub-regions would be identified as potentially suitable for grid (or off-grid) electrification. Further information-gathering would then be required, and preliminary design carried out in order to provide better information to enable higher resolution, particularly for borderline settlements. Further stages (including community consultation), will be required, before adequate information and conditions for project approval can be met, the last set of criteria needed. (See Table 1 of Annex B, which discusses the multistage Eskom project approval process). For each stage, different sets of criteria will be appropriate.

5.1.6 Criteria should not be immutable

In all cases, it is incumbent on electrification authorities to:

- evaluate regularly the costs, process, and effects of electrification, and use this to refine electrification decision criteria; and
- be flexible in the use of information and analysis for projects. This is particularly important given the widely differing levels of information available for different areas.

5.1.7 Criteria should assist short term planning – but an important objective is to support longer term planning

Grid electrification planners tend to be concerned primarily with identification of specific projects to be implemented in the next year or two. Network planning (bulk supply) has a longer-term time-frame, but this focuses on regions, rather than

[21] Knowledge of the available resource base is essential if grid/off--grid decisions are to be a result of grid planning (see **Figure 6**). However, if decisions are based primarily on comparison of technology options, then it may not be as necessary to have prior multi-year resource allocations made.

specific settlements. Off-grid planning, however, requires long time-frame settlement-specific information, as investments in off-grid technology are by and large sunk, and indeed wasted,[22] if grid electrification of a settlement subsequently takes place. In other words, one of the most significant risks that an off-grid service provider faces is the risk of grid electrification. Furthermore, even if grid electrification of a community is expected in, say, five years, off-grid technology may still be appropriate as an interim measure. However, the specific design choices would differ from those for a community where grid electrification is never expected. In the former case, greater use would be made of AC systems, gensets, or portable equipment that can be pulled out and relocated when the grid arrives. It is thus essential for communities and implementation agencies to know with some degree of certainty the detailed grid electrification plans for the next five to ten years. Otherwise unelectrified areas will tend to stagnate, with the communities, financiers and off-grid service providers unwilling to invest in alternatives to grid electricity, while they wait indefinitely for the grid to appear.

Uncertainty regarding grid electrification planning results in off-grid endeavours taking place in *very* remote areas, where the grid is very unlikely to approach. These areas are often the poorest, and thus the most difficult in which to achieve success. The best place for off-grid development to take place would be those settlements which *almost* qualify for grid electrification, but which will not be grid electrified in the next five to ten years. These are likely to have higher economic and development potential than more remote communities, and should be identified as early as possible. For such areas the key question becomes: 'How do we get a firm, accepted *decision* on grid planning so that we can move forwards?' Whether the decision process identifies the 'best' solution becomes of secondary importance, *so long as a decision is made.*

There is thus an emphasis below on the development of approaches and criteria that provide long-term planning information and that help to focus attention on the 'red line' between grid and off-grid. This is done in the knowledge that such long-term planning is inherently difficult and unreliable, given the changing dynamic of rural society. One is dealing here with risk management and probabilities. The field has not been fully explored but, as explained above, some attempt must be made, else 'off-grid' technologies will only be used in very remote (often very poor) areas, and those settlements in-between will simply wait (for better days?).

5.1.8 Different criteria for different types of finance?

Although the primary resource for electrification funding may be the assumed 'National Electrification Fund' (NEF), it is to be expected that others sources of finance will play an important role. Different categories of finance may have quite different objectives for money spent, and criteria to be met before funds could be released. A brief overview is given below.

Loan finance	• Project must be financially viable at the loan interest rate with an acceptable level of risk. • Once this criterion met, prioritisation can be according to a variety of criteria – as for other categories (equity, EIRR, social benefits).
Grant support	• Return on capital not required, but operational costs should be covered by revenue, (unless long term

[22] This problem is less severe if: the specific investments in off-grid electrification can be easily converted and used for the grid, or if assets can be moved at low cost to other areas. In a market were the same financier or service provider is responsible for both grid and off-grid electrification, this problem would be less severe, as managing the risk of electrification would be within the control of a single entity.

funding or cross-subsidy is explicitly agreed to).

- Criteria would be based on issues such as: equity, need, social benefit, and economic efficiency.

Investment by private sector or industry	• Return on investment (IRR) • Potential for synergistic benefits • In some cases the investor will have a 'social responsibility' component to investment prioritisation. In this case, maximisation of social benefit (preferably publicised) for a given resource allocation will be important. • Where the industry is regulated, criteria may be changed to meet conditions of licence (e.g. delivery of service to non-viable areas).
Cross subsidy within industry	• As for the above category. However, may be more strongly driven by social responsibility or conditions of licence. In the latter case conditions specified by the licensor will dominate, countered by the industry's priority to minimise losses and risks.
Community or individual finance	• Demand • Consumers' financial and welfare perspective (value for money, method of payment)[23]. • Free choice
National resources in the form of *grants* or *fiscal allocations* (National Electrification Fund)	Principal criteria will presumably be defined through an electrification policy development process. However, they are expected to include issues such as: • maximisation of economic return (national); • social equity; • maximisation of social benefit; • financial sustainability; • political criteria should preferably be excluded, or else made transparent, public and accountable.

The principle focus of this work is on criteria applicable to the allocation of national resources (as would be the case if there is a NEF), as it is assumed that resources from this fund will frequently play a decisive role in electrification decisions. Alternatively, one can consider the criteria and processes discussed below to be applicable to project planning and prioritisation, as it would be carried out by a body representative of different stakeholders in the electrification process who have the wise use of national resources as their primary objective.

5.1.9 National or operational level allocation of resources to specific technologies?

In section 3.1, reference was made to the possible levels in the resource allocation process at which specific allocations to either grid, or off-grid technology can be made. Three approaches are explored below:

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[23] For example, is the requirement for once off lump-sum finance (difficult), or for longer term, smaller amounts (easier, depending on level of flexibility and user control).

1) Resources are allocated to regions for *electrification*. Technology decisions (including the grid / off-grid decisions are then made at an operational level.
2) Regions are allocated resources for *grid* electrification, and a separate budget is allocated for *off-grid* electrification
3) Three different budget allocations are made: one for *grid* electrification, a second for *off-grid* electrification, and a third discretionary budget for *electrification* using any technology.

Option (1) (operational level technology choice) seems intuitively the most appropriate, as the policy decision, given effect through a national budget allocation process, is to provide an electricity service to communities. The most appropriate technology for electrification is then chosen at a local level in response to local conditions. The approach would require off-grid projects to compete directly with grid projects in the budget allocation process, hopefully encouraging careful comparative evaluation, and yielding a more integrated approach. It is possible, though, that off-grid electrification will be marginalised, especially if the costing approaches adopted in project evaluation do not take full account of the grid electrification costs. It has also been suggested by some participants at discussions (Second project workshop, DBSA 1998), that to place responsibility for deciding whether resources should be allocated to grid or off-grid on sub-regional level decision makers is unfair, as they are closest to the political heat. (This is arguably a good reason *for* these decisions to be made at a sub-regional level!).

Option (2), while lending a measure of stability to the off-grid industry (with market size at least partially defined through a national-level resource allocation process), and providing off-grid implementers with clear targets and objectives, runs the risk of perpetuating the current impasse between grid and off-grid planners. Separate budgets will tend to lead towards separate planning procedures and programmes. Greater emphasis would be placed on the selection of sites suitable for specific technologies (finding a market for a technology) rather than on the selection of settlements which have the highest priority for electrification, independent of technology (finding a solution to an identified demand). A national allocation of resources to off-grid is, however, a strong possibility, given the need to establish a vibrant, off-grid national agency and dedicated financing infrastructure. The tendency for international donors to make large-scale funding available only for specific technologies also provides impetus in this direction.

Option (3) is attractive, in that it would allow provision for separate dedicated funding sources, providing a minimum base level of activity for the off-grid programme. However, if the technology independent budget is a sufficiently high proportion of the total, this should encourage interdependence and integrated grid/off-grid planning.

The discussion in the following section is premised on the assumption that planning will be reasonably integrated, and that the primary objective is electricity service delivery, independent of the technology chosen. However, as will be seen in the two approaches suggested, either could be adapted to work within any of the three national-level resource allocation processes discussed above.

5.2 Two approaches to technology choice

When the service offered to a community or household through the use of off-grid technology is essentially the same as that offered using grid (with similar potential for growth in demand), then it is a relatively simple matter to assess the technical, financial and even economic costs of supply, and choose the most appropriate supply technology. However, where the quality and level of service delivery is substantially different, the issues become more complex, as the comparative evaluation of significantly different social and economic costs and benefits to households, businesses and communities is no easy task.

Two different approaches to the sub-regional planning process have been identified. The approaches are similar for situations in which decisions regarding technology choice are fairly easy to make. They differ in the approach to cases where technology choice (or level of service decisions) are less clear cut – the 'borderline' cases.

The first methodology assumes that planning decisions will be dominated by grid planning constraints and priorities. The essential question is: *When can a given settlement be connected to the grid?* The decision to use off-grid technology for the settlement is a result of the grid planning approach. If the planned grid electrification date is too far in the future or 'never', then the area is by default an off-grid area. For the purposes of discussion this is referred to as the 'grid prioritisation' approach.

The second approach assumes that technology choice can flow from a rational evaluation of settlement characteristics, energy requirements and a social/technical/economic assessment which seeks to determine the most appropriate technology for a given situation. Thus the primary decision is: *Which technology should be used to meet the needs of this settlement?* Questions of prioritisation are approached in a subsequent phase. For the purposes of discussion this approach is referred to as the 'rational technology' approach.

Overviews of these approaches are presented in Figure 6 and Figure 7, and a more detailed discussion of each approach and the applicable criteria is presented in sections 5.3 and 5.4.

Figure 6: Grid prioritised sub-regional planning

Key principles and assumptions

- Grid connection is the strongly preferred option for a variety of reasons (not all readily quantified).
- Accept that economic, financial and social benefits analysis is adequate to prioritise projects which deliver comparable benefits (at least in the first instance).
- Acknowledge that economic analysis is a relatively blunt instrument to rank options that deliver significantly different benefits (i.e. that 20 A grid vs. off-grid decisions cannot easily be made on the basis of techno-economic analysis, particularly in borderline cases).
- As a result, off-grid areas are defined primarily a result of carefully prioritised long term grid planning, carried out in the context of a defined financial and institutional grid electrification resource.

Steps in the planning process

Process	*Criteria*
Step 1: Identify areas/settlements/hh of region where grid is definitely not viable during planning period (say 7 years).	Estimated cost of grid electrification above agreed maximum (y Rands per connection) Indicators: Large distances between households and/or settlements, small settlement sizes, low wealth index, few public facilities.
Step 2: For remainder of region, carry out grid plan based on agreed ADMD for hh. Include known community and commercial loads.	Best practice electrification and network planning (70% level of certainty).
Step 3: Review plan to identify and remove from grid plan areas and hh which are too expensive.	Cost per connection higher than maximum (as for step 1).

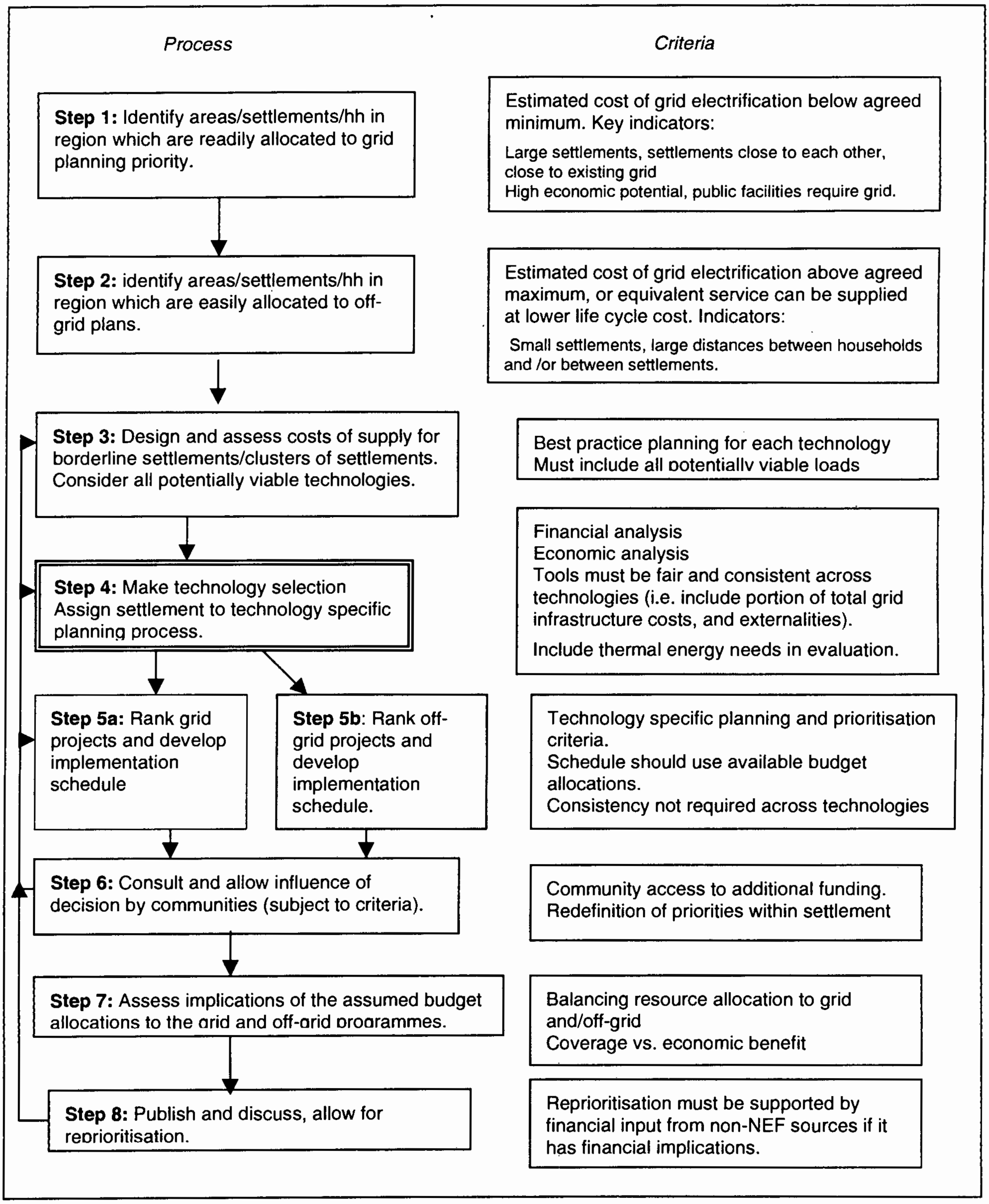
Step 4: Rank all remaining electrification projects in order of priority for electrification.	• Financial NPV
	• Economic NPV or CBA
	• Modified as follows:
	  • Social service given high priority
	  • Consideration of other development initiatives

Step 5: Use the ranking to develop possible electrification programme plans with approximate dates of project implementation.	Different plans would be generated using the information from steps 3 and 4, depending on the level of resources allocated to grid electrification.
	For each grid plan, there will be an implied complementary identification of off-grid areas. This will comprise those areas identified in steps 1,and 3, as well as those which do not rank sufficiently high on the priority list (step 4) to be connected within the planning time and budget schedule (step 5).
Step 6: Select a grid electrification plan.	• Balancing resource allocation to grid and/off-grid. • Coverage vs. economic benefit.
Step 7: Publish, and discuss Allow for reprioritisation.	Reprioritisation must be supported by financial input from non-NEF sources if it has financial implications.

Figure 7: 'Rational technology' selection approach

In the more critical borderline cases, a careful technology choice is made, rather than allowing the grid/off-grid decisions to be essentially a by product of a grid planning exercise. This approach requires:

- An accurate social, technical and economic evaluation of grid / off-grid costs and benefits which has a sufficient level of confidence to allow robust grid/off-grid decisions.
- In order to improve decision making accuracy, it is recommended that thermal needs (and energy supply options that meet these needs) be included in the evaluation.



5.3 Description of the 'grid prioritisation' approach

Side-stepping comparative assessments of different service levels

Key principles and assumptions

- Grid connection is the strongly preferred option for a variety of reasons (not all readily quantified).
- Accept that economic, financial and social benefits analysis is adequate to prioritise projects which deliver comparable benefits (at least in the first instance).
- Acknowledge that economic analysis is a relatively blunt instrument to rank options that deliver significantly different benefits (i.e. that 20 A grid vs. off-grid decisions cannot easily be made on the basis of techno-economic analysis, particularly in borderline cases).
- As a result, off-grid areas are defined primarily a result of carefully prioritised long term grid planning, carried out in the context of a defined financial and institutional grid electrification resource

5.3.1 Criteria for 'easy' decisions (Step 1 for both approaches)

Both planning approaches require that a first-pass planning exercise (Step 1) be carried out to identify:

- settlements and clusters of settlements that have a high priority for grid electrification;
- settlements where the choice is not obvious – further analysis needed;
- settlements where grid electrification is extremely unlikely, and off-grid electrification should be used.

The principal information available would be:

- settlement size (number of households or population);
- density (number of households/area of settlement);
- distance to nearest settlement;
- number and location of public facilities such as clinics and schools;
- wealth indicators may be available, and if so should be utilised to estimate consumption and willingness to pay.

This type of decision-making is common to both approaches, and is discussed in more detail in section 5.5.

5.3.2 Electrification planning (steps 2 and 3 of 'grid prioritisation' approach)

Once settlements (and areas) that are clearly *not* suitable for grid connection have been eliminated from the grid planning process, the 'grid prioritisation' approach requires that preliminary network and grid electrification planning be carried out for all remaining settlements. This is to provide a more accurate cost per connection for the different settlements. In the first instance, such planning should cater for a relatively low ADMD (0.4 – 0.7 kVA). Best practice planning and costing approaches should be used, with some optimisation required in order to reduce costs. During the planning process, rank outsiders should be transferred to the 'off-grid' category as more detailed information on costs becomes available. Such outsiders may be either entire settlements, or individual households or portions of settlements where the specific capital costs per connection are unacceptably high.[24]

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[24] It is not possible to place a figure on the term 'unacceptably high' at this stage. A figure of twice the average costs per connection for the *region* would be appropriate in the first instance. The value can be refined as soon as stages 4 and 5 have been carried out.

As part of this planning process, information for the next stage of prioritisation should also be collected.

5.3.3 Criteria for ranking electrification projects (Step 4 of 'grid prioritisation approach')

Prioritisation of projects is necessary to allow final project scheduling and allocation of resources available in particular budget periods to particular projects. This is likely to be the most controversial component of any electrification planning process. In the approach to technology selection discussed here, prioritisation of grid projects is at the crux of grid/off-grid decision making as well. Careful analysis and definition of criteria are thus required. The task is, however, simplified, in that one is primarily comparing like things (one grid project against another grid project), not unlike things, as in the case of grid /off-grid decisions.

Ranking of electrification projects should take account of the following factors:

- Capital cost per connection – this is important given defined constraints on access to capital.
- The consumers' perspective – the benefits that will accrue, and the costs incurred.
- Net present value of project – financial analysis, considering the utility point of view over a 15 to 20 year period (this requires some assessment of expected consumption).
- Economic analysis – considering the benefits and costs from a national perspective.
- Technical and institutional considerations – is electrification feasible and institutionally manageable in the longer term?
- The social benefits and costs that will accrue.
- Development potential, with areas of higher potential allocated a higher priority.

By this stage in the planning process there is significantly greater information availability, and it is possible to:

- use project/settlement specific financial and economic analysis.
- use project/settlement specific estimates of consumption.
- to engage directly with other infrastructure planners regarding developments in the area.

The reader may wish to refer to Table 5 for a more complete listing of important factors. A specific approach and the most critical criteria applicable to this level of prioritisation are considered in more detail in section 5.6 following.

The output of the ranking process would be a list of possible electrification projects, listed in order of priority, with budget requirements for each project already specified (as a result of Step 2 of the panning process).

5.3.4 Electrification plan development, and selection of particular options

Once the above described prioritisation process has been carried out, it would be possible to develop a multi-year grid electrification programme (with budget), based on defined resource allocations and implementation capability for the planning period. The plan would assume that electrification sequencing is based primarily on the above determined prioritisation list. However, technical project sequencing considerations would also play a role.

Settlements at the bottom of the list would not find a place on the electrification plan during the planning period (assuming that the available resources are insufficient to electrify all settlements) and would thus by default fall into the 'off-grid' planning area. For all higher ranked settlements, a given rate of resource allocation would result in an expected electrification date.

Knowledge of the expected date of grid electrification would considerably facilitate interim provision of alternative energy services using off-grid technology. Settlements expecting electrification in two years time may wait. Those expecting the grid in three to five years would presumably utilise technology which can either be integrated into the grid, or which can be readily moved on to other locations. For school and clinic systems this will tend to mean that AC lighting should be used, with gensets or possibly PV arrays coupled with inverters and mounted in such a way that they can be removed and reused when the grid arrives.

In the concept presented in **Figure 6**, it is assumed that the level of electrification resources allocated to the planning region has already been defined as per **Figure 2**. If this is not the case, then the planning information resulting from the above exercise would inform the higher level resource allocation process. This would be a valuable upward flow of information.

Within the planning region, the split between grid and off-grid resource allocation may also not yet have been made. To support decision-making regarding the split of resources to grid and off-grid, different electrification plans could be developed at the sub-regional planning level. The first option might assume that all resources would be allocated to grid electrification. The second would assume that 25% of the available resources are allocated to off-grid technology, and the third may assume that 50% of the available resources are allocated to off-grid technology. Options which have a higher percentage of 'off-grid' allocations are likely to reach a greater number of people for a given financial resource (greater coverage), although the net economic benefits may not necessarily follow the same pattern. The choice of a particular resources allocation should be informed by sub-regional programme financial and economic analyses (which could be readily carried out through aggregation of project-level data produced in stage 4). Decisions should also be informed by detailed financial, social and economic analysis of a small sample of the 'borderline' projects for each scenario.

A number of iterations between stages 3 and 4 will be required, as the settlement specific costs of grid electrification for particular settlements will be affected by decisions to take nearby settlements off the 'grid' electrification list. Redesign of transmission and bulk supply networks may be necessary.

5.3.5 Final stages of the 'grid-prioritised' sub-regional planning process

Once a particular resource allocation to grid has been selected by decision makers, it would be possible to publish a provisional electrification plan, listing settlements to be electrified, and approximate dates of electrification.

- Communities and alternative funding agencies should be given an opportunity to modify plans and ranking, through:
  - commitment of funds or other resources (labour, poles) from sources other than the NEF;
  - the concrete expression of material differences of priorities within communities to those assumed;
  - presentation to the planning process of new information which substantially alters the basis of assessment.
- Although the plan should maintain a long-term focus, it should also be reviewed regularly and adjustments made in the light of experience, changes in resource availability, or changes in settlement socio-economic conditions.
- Detailed evaluation and analysis of a representative sample of 'borderline' communities should be carried out to ensure that it is indeed sensible to electrify the lowest ranked villages which appear on the *grid* electrification plan.
- There should be some iterative cycles, and feedback of data from more detailed analysis to inform criteria for preliminary decisions. For example, information on settlements that are identified as 'borderline' grid projects can be used to

check the stage 1 criteria used to exclude easily identified off-grid projects from the ranking process.

5.4 The 'rational technology' selection approach

Facing the question of comparative service levels and different technology options head on

This approach has similar preliminary steps, in that grid and off-grid areas that can be easily distinguished at the outset are identified. However, in the more critical borderline cases, a careful technology choice is made, rather than allowing the grid/off-grid decisions to be essentially a by-product of a grid planning exercise. This approach requires an accurate social, technical and economic evaluation of grid / off-grid costs and benefits which has a sufficient level of confidence to allow robust grid/off-grid decisions. Furthermore, in order to improve decision making accuracy, it is recommended that thermal needs (and energy supply options to meet these needs) be included in the evaluation; see Figure 7.

5.4.1 Criteria for easy decisions (Steps 1 and 2)

There will be a number of cases (perhaps even the majority) where the grid / off-grid decision is relatively straight forward, as discussed in section 5.3.1. Settlements should be assessed, using the principles discussed in section 5.5, with little further requirement for extensive analysis. The following broad groups can be identified:

1. Settlements and clusters of settlements that have a high priority for grid electrification.
2. Settlements where the choice is not obvious – further analysis needed.
3. Settlements where grid electrification is extremely unlikely, and off-grid electrification should be used (or no electrification).

However, as a significant number of economically more attractive off-grid projects are most likely to be found in the second group (these will tend to be larger settlements with greater economic potential), it is vital that further analysis be carried out on this group as soon as possible.

5.4.2 Technology selection (Step 3)

At this stage in the decision process, the aim is to gather sufficient data, and process it in such as way as to allow a decision to be made regarding the most appropriate technology choice for settlements (or clusters of settlements) falling into the second group identified above. The focus of interest is thus on settlements where there is no ready answer. They are near the 'red line' between grid and off-grid areas.

As in the case of prioritisation of grid projects, a number of different perspectives are important – householder, businessperson, community service provider (health, education, etc), and energy service provider. Furthermore, one is generally not comparing 'apples with apples', but rather 'apples with smaller and perhaps less tasty figs'! To date, we have little concrete information on demand for off-grid systems, and very little experience of pay-back rates. It is also not possible to quantify with any degree of certainty the possible benefits, particularly for productive activities, of off-grid electrification. As a result it is not clear that a widely accepted approach to decisions can be found – hence the 'grid prioritisation' strategy proposed above. Nevertheless, certain decision-making tools are available, and for the present, carefully conducted financial and economic cost/benefit analyses will provide the best indicator for decision making.

Key principles are that:

- The decisions should be based on a comprehensive (integrated) analysis of electricity needs (preferably energy needs) in the communities.

- Off-grid costing will require good knowledge of specific loads and user requirements. Thus, local-level knowledge and interaction with potential clients is necessary.
- Costs should reflect the 'full picture' (particularly for grid proposals, as the costs of bulk supply, peak loading, network development, and externalities are not always fully reflected in costing exercises.)

The main issues are presented for consideration in section 5.7.

5.4.3 Ranking of projects (Steps 5a and b of Figure 7)

Ranking of those projects identified as *grid* through the above process could follow a similar methodology to those outlined in section 5.6. For *off-grid* projects, a similar process of identifying the projects with the greatest economic or financial potential benefit would be followed once a large-scale off-grid programme has been established. However, at least in the initial stages of off-grid activity (pilot projects)[25] in the country, prioritisation is likely to be dictated by issues such as:

- expressed customer demand and acceptance;
- development linkages made by agencies (for example household programmes may follow school and clinic off-grid programmes);
- availability of the necessary support infrastructure for solar system dissemination (finance facilities, maintenance provision).

5.4.4 Consultation and reprioritisation of projects (Step 6 of Figure 7)

Technology decisions have significant implications for the community as a whole, even if off-grid decisions may be perceived as individual, or sector-specific. For example, if a school and clinic are equipped using off-grid technology, this will weaken subsequent applications for a grid connection to the entire community, as the additional benefits of grid electrification to the agencies responsible for health or education delivery will be significantly reduced (and hence their willingness to pay). Furthermore, if community members perceive the use of off-grid technology by some households, schools or health posts as weakening the community's position in negotiations around grid prioritisation, this can lead to animosity and possibly vandalism of equipment. Community consultation and involvement in technology decisions is thus vital. While the technology choice may not be perceived by consumers as being optimal (most will demand grid), the reasons for decisions should at least be clear and properly communicated. (This is an argument for tariffs to be adjusted such that they provide a better indication of the full cost of supply – particularly for grid technology). A key component of such community debates will be accurate information on costs and benefits, as well as information on project scheduling. There should be opportunity to change grid/off-grid decisions if communities can access the necessary resources, and/or bring additional information to the table.

5.5 First-pass decision making

Both decision-making approaches to technology choice and electrification planning discussed above require that a preliminary evaluation of all potential electrification projects in a region be carried out, and that settlements be grouped as follows:

1. Settlements and clusters of settlements that have a high priority for grid electrification.
2. Settlements where the choice is not obvious – further analysis needed.
3. Settlements where grid electrification is not viable under current conditions, and off-grid electrification should be used.

The principal information required for this first-pass analysis is:

- settlement size (number of households);

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[25] For a listing of criteria for the identification of pilot solar home system projects, the reader is referred to annex 17 of Cowan *et al* (1996a).

- density (number of households/area of settlement);
- distance to nearest settlement;
- number and location of public facilities such as clinics and schools;
- wealth indicators may be available and, if so, should be utilised to estimate consumption;
- furthermore, maps of existing grid (and any already determined plans for grid extension) would be required;
- thus for each unelectrified settlement, the approximate line extension length required to achieve electrification can be determined;
- in addition, information on any infrastructure, agricultural or other development initiatives should be gathered and incorporated in the decision making process.

The principle criterion to be used for this first pass categorisation is the expected capital costs of reticulation and settlement-specific grid extension (not general network development). Those settlements or clusters of households which have a 'specific capital cost'[26] much higher than norms for the grid electrification should be excluded from further analysis.

The IDT has used distance from the grid as first pass indicator for technology choice with some success. One can for example decide that all settlements within five km of the existing grid infrastructure should be electrified in the near future. See Figure 1 for an example of how this criterion can be translated into spatial information on a GIS system. Such an approach, while satisfactory in the first instance for clinic or school technology decisions, is, however, inherently incremental and has no logical stopping point. Each year the grid would extend further, in all directions, and in a somewhat arbitrary manner, with little regard for settlement size, or differentials in expected consumption.

As an alternative, the following multiple index approach is suggested. Firstly, the settlements in the planning region should be divided into categories according to an index which reflects the expected capital cost of electrification. In most areas of the country, this would be the sum of two sub-scores:

1. a reticulation cost sub-score based on the density of households within the settlement; and
2. a line extension sub-score based on the ratio[27] of the total number of connections and the minimum length of line extension required.

For very small settlements (less than 50 households), where density information may not be available, it is suggested that a low density (less than 80 hh per km^2) be assumed. In certain areas, (see section 2.3.3.1 of Annex B), density is not a useful parameter. In this case the total length of both MV and LV line required would have to be estimated, probably manually, and a formula such as that suggested by Stephen (1997) utilised.

If the above-line extension score was based on distance to the nearest existing (or planned grid line), it would not account adequately for possible sharing of line extensions by two or more communities. Using distance to the nearest grid as the denominator would also seriously disadvantage clusters of settlements which may

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26 Specific costs are usually expressed as a cost per connection. Thom (1998) suggests that it may be more appropriate to use the costs per person benefiting from electrification, as an indicator, as household sizes can vary significantly. The implications of a shift to analysis on a per person rather than a per connection basis have not been explored as part of this work.

27 This sub-score would have units: connections/km. The assumption here is that the contribution of line extension cost to the total capital cost per connection decreases in proportion to the number of connections for any given line extension distance. This is not entirely accurate. It would be relatively simple to derive a more accurate indicator that takes into account differences in cost for different line capacities (VA).

together form a viable grid electrification project. It is therefore recommended that, for the purposes of first-pass ranking, the line extension distance be taken as the *lesser* of either:

- distance to the nearest grid; or,
- distance to the nearest settlement of similar or greater size.

If the latter distance is used, one is implicitly keeping bulk supply costs and HV transmission line extension costs out of the first-pass ranking process. This is intentional, as these costs require more detailed planning to determine, and should rather be included in decision making in a second pass process (section 5.6).

Both sub-scores could be calculated using a GIS based database. Provided that appropriate weighting is given to the reticulation and the line extension components, the combined score for each settlement would give a fair indication of the minimum expected capital requirement for grid electrification. The results could be plotted on a map with different colours assigned to different settlements according to the scores.

Those settlements which have very high capital cost scores relative to the others would be defined as 'off-grid' settlements, those with low capital cost scores defined as 'grid' settlements, and those in the middle defined as 'uncertain', requiring further analysis. The boundary scores for the different categories should obviously be defined with care. It is important to note, however, that the aim is *not* to have high resolution at this stage in the planning process. Provided that the 'uncertain' band is wide enough, few errors will occur in allocations to either the 'grid' category, or the 'off-grid' category.

It is possible to include indicators of wealth (and hence expected consumption – see section 4.3.2.2), and indicators of social benefits that will accrue from electrification (improvements in water supply, clinic electrification and school electrification) into the above settlement index. However, further research would be required before a combination index could be used with confidence. For present purposes, it is rather recommended that:

- locations of schools and clinics be overlaid onto the above map;
- locations of known significant business or agricultural development be overlaid onto the map;
- settlements with adequate water supply be highlighted.

These overlays should be used to justify reclassification of settlements from one category to another. For example, a settlement with a borderline score that places it just within the 'off-grid' area could be moved to the 'uncertain' category because it has a high wealth index and a school or clinic. Similarly, a settlement with a score near bottom of the 'uncertain' category could move into the 'grid' category because it is close to a proposed agricultural development.

Particular care should be taken when classifying settlements into the 'off-grid' category at this stage. Settlements in the 'uncertain' and 'grid' categories will be re-evaluated in a second-pass process (refer to Figure 6 and Figure 7). However, settlements classified at this stage as 'off-grid' will not easily be considered for grid electrification again. For this reason it is suggested that communities allocated to the 'off-grid' area at the first-pass stage be allowed to apply for a more detailed evaluation of their situation on request.

5.6 Electrification project prioritisation

This section of the report deals with the criteria that should be applied for a more rigorous prioritisation of settlements for grid electrification (Stage 4 of the 'grid prioritised' approach outlined in **Figure** 6). However, many of the issues discussed, and the criteria suggested, are relevant to stages 4 and 5 of the 'rational technology' approach as well (**Figure** 7).

As a first step it is recommended that all projects under consideration be ranked according to a financial analysis (NPV per customer) and secondly, according to an economic analysis (economic benefit to cost ratio, or EIRR). These analyses should look at the settlements as a whole. Attention should be paid to non-domestic loads, community service loads, and to the identification of opportunities for the beneficial use of electricity in income generation. The analysis should use *settlement specific* data for at least the following inputs:

1. Capital cost of grid electrification with a level of certainty of 70%. (This information would be available from Step 3 of the planning process).
2. Number of households and population (generally available on existing databases).
3. Percentage of households within settlement that will be electrified (this would be an approximate figure – for the most part coverage is close to 100%, but in some regions outlying households would not be electrified due to high specific capital costs).
4. An assessment of the number and scale of business activities in settlements (not readily available, but sample surveys should be carried out to determine average conditions, and an effort should be made to identify settlements which have significantly more or less than average economic activity).
5. Number of schools and clinics in or close to settlements (generally available on existing databases).
6. Specific opportunities for extra benefit (improving water supply, agricultural development or entrepreneurial activity that is expected to result from electrification).
7. Wealth or some other indicator of expected consumption and willingness to pay. (See sections 4.3.2.2 and 4.3.2.3 for further discussion of this vital area. Again, it may be necessary to use regional averages to start with. However, the recently available census data on income could be used to modify figures for settlements.) Other possible indicators of higher than usual average demand include:
   - strong women's groups, which may be able to exercise sufficient power to use electricity;
   - a scarcity of woodfuel, or a commercialised woodfuel market, indicating that thermal needs are a high priority.
8. Technical and non-technical losses: experience of grid electrification in the planning region should be used to estimate technical and non technical losses, for input into the financial and economic analysis.

This seems an onerous task; however:

- The process can be completed in a number of passes, with the level of confidence of input data being allowed to vary according to the sensitivity of the decisions being made.
- Projects that are clearly not suitable for grid electrification can be cut out of the more detailed evaluation process at an early stage, on the basis of first-pass information, thus one is focusing on projects that have a reasonable probability of being electrified.
- Economic and financial analysis is already an established component of the electrification project cycle.
- The effort required to determine capital costs of electrification is not unreasonable, given the software tools available and the considerable experience South Africa already has of electrification projects.
- Unless settlement data on business activity, community facilities and wealth are determined and factored into revenue stream and benefit assessments, electrification planning will continue to be driven by least-capital-cost considerations.

- The cost of settlement electrification is considerable. There is significant variation in the costs, and benefits achieved for different projects (see Figure 3 as an example of one facet). It is therefore important to make wise decisions.

Particular attention should be paid to good data collection for projects which are ranked near the bottom of the list (low EIRR or highly negative NPV). These are the 'borderline' settlements, and require the most careful decisions. Prioritisation of settlements that have high EIRR, and positive financial NPVs (or at least require the least subsidy) matters little. They will presumably all be grid electrified in the near future.

As discussed in section 4.3.1, the choice of whether to place primary emphasis on the economic or the financial analysis results derived above will depend primarily on the guiding electrification policy (which has yet to be defined). If the objective is to utilise the resources to achieve as wide a coverage as possible, then the financial analysis will be more important. If, on the other hand, economic efficiency is the main concern, the EIRR (or economic NPV) will be more important. Until such time as a policy for electrification funding allocation has been defined, it would be appropriate to rank projects according to both indexes (making two prioritised lists). These lists should then be reviewed by a committee,[28] with a final list being made which takes into account the financial, economic and other considerations discussed below.

The above estimation of financial and economic returns to be expected for each settlement (if electrified) would provide an important resource. It should not however be seen as the final, prioritised electrification plan to emerge from this part of the planning process.

Adjustments should be made on the basis of the following:

1. Settlements which are of significant importance (relative to others) in the region, should be moved up the priority list. These can be identified through the following indicators:
    - settlement size;
    - presence of schools, health facilities, and public administration offices;
    - location with respect to important transportation routes.

   (Note that, in both cases, the economic analysis will have accounted for this in some measure already, and it is thus not clear that ranking should be altered on these grounds).

2. Planning authorities should actively engage with other planning and development initiatives in the region, to share and gather information. Of particular importance would be 'Development Corridors' and 'Spatial Development Initiatives'. Settlements that are likely to contribute to, or benefit from, these planned initiatives should move up the priority list. Due cognisance should be taken of appropriate project scheduling.

3. Settlements which have inadequate water supply, or for other reasons are not viable as permanent places of residence, should be moved down the priority list, unless defined plans are in place to improve the situation. If supply of the grid will contribute to this improvement, then this should be included in the economic analysis.

4. This review of the priority listings should be carried out with the aid of area maps, which show the relationship of settlements to each other, and to the major proposed grid extension routes. Due cognisance will have to be taken of the interdependence of specific settlement project viability on the electrification of nearby settlements.

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28 No recommendation is made here regarding the choice of representatives who should sit on that committee.

5.6.1 Assigning values to not easily quantified parameters and including them in an extended economic analysis

It will be noted, through reference to Table 5, that there are relatively few factors which directly affect electrification project prioritisation that are not accounted for in the economic analysis. The committee-based adjustment of priorities would therefore be quite limited, and manageable. If deemed necessary, however, it is possible to explicitly quantify concepts using a standardised score sheet or methodology, that is applied to all electrification projects. The economic analysis model applied to electrification projects can then be modified to include these standardised revenues, expenditures or once-off costs and benefits. As the prioritisation process is a relative process, with similar types of benefits occurring in different communities, a lack of absolute rigour in determining these standardised costs and benefits is acceptable, provided that the formulae are applied universally. For example, the socio-economic benefits accruing as a result of electrification of schools have not been economically quantified, and considerable uncertainty exists regarding the benefits which accrue. Current economic models assign a 'willingness to pay' for grid electricity equivalent to that of supplying the next best alternative (a PV grid system). This typically equates to a once off willingness to pay of approximately R60 000. As an alternative, educationalists might argue that a 'willingness to pay' factor of say R0.50 per month per pupil at a senior school (equivalent to R2 400 per annum for a school with 400 pupils) could be assigned to electrification projects which will include school electrification. This translates a policy decision into a monetary indicator which can readily be included in the economic analysis. Similarly, health facility improvements, or upgrades to water supply as a result of electrification could be assigned standard values according to agreed formulae. These can then be utilised in a quasi-economic analysis. It is strongly recommended that results from such 'quasi-economic' approaches be reported separately to those from the more conventional economic analyses, particularly while their merits are still being assessed.

5.7 Criteria for 'rational technology' based decisions

This section of the report aims to present criteria that would assist decision-making at a project level regarding the most appropriate technology to be used. Such criteria would primarily be used at stage 4 of the 'rational technology' approach. They would also be useful whenever decision-makers are required to make single project decisions, as opposed to making decisions within a larger electrification programme (for example when evaluating proposed changes to long term plans). In a similar fashion to that assumed in section 5.6, the focus is on settlements where decisions are more difficult to make, a preliminary screening using the criteria listed in section 5.5 would already have been carried out.

As for grid prioritisation, the most powerful aid to decision-making will be financial and economic analysis of the different technology options for given settlements. Such analysis will require a similar level of detail to that described in section 5.6, with the following important additions, because one is comparing two such different technical approaches:

- The capital and life costs of grid technology should include:
  - externalities on the generation side (costs);
  - health and related externalities on the customers side (generally benefits);
  - the full costs of grid extension should be factored in (including a share of bulk supply); however, as for the grid prioritised approach, sharing of bulk supply costs between different settlements should be applied;
  - the effect of the peaky nature of domestic loads on the cost of electricity supply should be included in the analysis
- Economic opportunities (and constraints resulting from supply choice) should be reviewed and included in the analysis.

- Given certain off-grid technology's considerable cost sensitivity to load magnitude and load factor, it will be necessary to identify all significant loads, and include these in the analysis (water pumping, health centre, schools, SMME requirements).
- As grid technology has the potential to meet some thermal needs, but off-grid technology usually does not, it is recommended that the costs and benefits of energy for thermal energy needs be included in the analysis.

For an example of an evaluation which includes many of the above elements see Davis (1997).

A key difficulty in assessing the potential economic or financial costs and benefits of off-grid electrification options, is that we do not yet know what the levels of demand from communities will be. In grid electrification projects, most households elect to take a connection. In off-grid programmes, however, the uptake rate will be strongly dependent on the initial and subsequent repayment rates required. Where deposits of the order of 10% have been required, the demand for SHSs has not been very high (approximately 40 systems in the community of Maphephethe over a 24-month programme period (Cawood, 1997). In the community of Kwa-Bhaza about half the households have expressed interest, but it remains to be seen how many will actually take the SHS and gas package being offered (Kloot 1998). For the present, decisions will have to be made based on assumptions regarding take-up rates, repayment rates, and the cost of providing maintenance and long term service. Information based on experience should be included as soon as possible.

Even with good information, the deductions to be made from such comparative financial and economic analyses are not always immediately apparent, given the significant differences in level of service offered by grid and off-grid technology. Consider the following hypothetical situation:

> Settlement A, located ten kilometres from the national grid, has applied for electrification. The settlement has a school, the nearest clinic is already electrified and is 15 km away. The community has adequate water availability for domestic consumption. Agricultural potential in the region is marginal, and unlikely to be significantly affected by electrification. Table 7 indicates the results of a comparative evaluation of grid electrification, and electrification using solar systems. (Please note, all figures are entirely speculative, and presented to facilitate discussion only; neither a financial or economic analysis has been carried out.)

Table 7 Example of hypothetical settlement analysis results

Settlement data	
Number of households	100 of which 10 have businesses
Distance from nearest grid	15 km (0.150 m/connection)
School	Yes: Primary, 300 pupils
Clinic	No
Water supply	Already adequate
Tariff: grid- prepayment meter option	R50 connection + 30 c/kWh
Expected average consumption after 5 years (if grid)	80 kWh/month
Expected take up rate (grid)	90 %
Cost to user (off-grid)	Small system: R50 'connection' + R15/month Medium syst: R300 'connection' + R25/month
Expected take up rate (off-grid)	60 % of households take small SHS (R1500) 30 % of households take medium SHS (R3500) 10 % of households do not utilise SHS

Cost/benefit item	*Grid*	*Off-grid*
Capital cost of electrification (hh)	R450 000	R 195 000
Cost to electrify school	R5 000	R40 000
Consumers cont. to capex	R4 500	R12 000
Ext. capex required	R450 500	R223 000
Monthly revenue	R2 160	R1 650
Operating expenses	R1 620 (R18/system)	R1 350 (R15/system)

Assume for the sake of argument that the financial and economic analysis yielded the following results:

Financial NPV per customer (20 years)	(R4 500)	(R2 000)
Economic NPV per customer (20 years)	R2000	R 1000
Economic B-C Ratio	1.4	1.5

What decision should be made, and how?

From the household perspective, the choice would almost certainly be for a grid connection (see discussion in section 4.4.1). Not only are the consumer financial benefits likely to be higher, the grid option allows greater flexibility for growth, and has a higher status and appeal. Unless connection fees and tariffs change, or there is a firm statement from 'somebody' that the grid will not be available, or else only in a number of years time, (see 'grid prioritised' planning approach), the community is likely to be unhappy with an off-grid solution.

Thus, at present tariff levels, the final decision-making power cannot rest with the community unless:

- both grid and off-grid technologies are supplied with a broadly equivalent subsidy level (i.e. tariffs are adjusted); or
- communities leverage funds from sources external to the National Electrification Fund which can be used to make the more expensive grid option more acceptable to the service provider.

From a service providers perspective, the objective would be to maximise financial return, or (if driven by a social responsibility or target agenda) to minimise the loss. Given the above financial figures, the service provider would presumably favour the off-grid electrification route. This allows the settlement to be nominally electrified at substantially reduced capital cost, and with a lower project life cost (total NPV of the off-grid option would be less than half that of the grid option).

For a National Electrification Fund, the decision is less clear. Are national level economic benefits and costs more important, or is the priority to get as many households as possible equipped with a basic level of service? The answer lies somewhere inbetween. (See section 4.3.1 for further discussion of this point). Decisions should probably be made on the basis of the *financial* analysis provided that in cases where the economic benefit of the grid option is *significantly higher* than that of the off-grid option, grid electrification should be followed even if on the basis of a financial analysis the 'off-grid' option would require less resources. To date, there is very little South African experience of the actual costs and benefits of off-grid electrification from a social or economic perspective, and it is difficult to quantify what is meant by this use of the phrase '*significantly higher*'. Careful field based evaluation of projects is required. The question will be resolved in part through the pressure of resource constraints, and in part through availability of better information as case studies of off-grid electrification are carried out.

Uncertainty regarding social benefits of both off-grid and grid electrification also makes it difficult to provide recommendations regarding the incorporation of less readily quantified costs and benefits into the technology selection process. The approaches noted in section 5.6.1 would be of some use.

5.7.1 Options other than SHS

The example listed above used stand-alone SHSs as an alternative to grid electrification. As discussed in section 2.3.2, there are a number of other options to off-grid electrification. Project planners should take care not to ignore the potential of options such as mini-grid, battery charging systems, or solar lanterns. The criteria for technology selection will remain as above (with financial and economic analysis being the primary analysis tool). The reader is also referred to Table 2, for cost indicators that will help to alert planners that a particular technology should be considered.

5.8 Community involvement in decision making

Prioritisation, and the grid / off grid decision are essentially both a result of resource constraints external to the communities involved (capital, institutional capacity, sustainability of cross-subsidies). It is also generally acknowledged that communities strongly prefer grid electrification and their vote is therefore assumed to be cast. Financial analysis from the consumer perspective supports this assumption (see section 4.4.1), as does the experience of people involved in efforts to promote off-grid electrification. As a result of the external constraints, the decisions tend to be taken by outsiders (the utility, the NEF). Nevertheless, there is a strong tension between a knowledge that it is better to plan with, and a propensity to plan for. A measure of external decision making can be accepted for the key decision of whether or not a community will get access to the grid, and in questions of priority (when that access occurs) relative to other communities. Two important provisos should be noted:

- If a community does not want a particular electrification option, then this must be respected.
- If a community can bring extra resources to the table (financial or other), these must be factored into the financial and economic analysis carried out, and should result in changes in prioritisation or even of technology choice.

Care should be taken to ensure that community involvement and participation is maximised in the actual electrification project detailed design and implementation. This is especially important for off-grid projects, where sustainability will be strongly dependent on user care of systems, and possibly on local maintenance and service facilities. There is thus a need for a shift in planning approach. For example, once a decision has been made that an area cannot be grid electrified, then a more interactive development of the optimum off-grid energy solution for the community should be developed in a participatory manner.

5.9 Criteria for final approval of projects

Once reasonably detailed planning has been carried out for electrification projects (of any type), it is assumed that a formal application for funding would be submitted to both the utility capital investment committee, and to the electrification fund authorities.[29] This would be submitted in the context of a prioritised programme plan, but would nevertheless form an important formalisation and check that specific requirements have been met. Criteria for this stage should go beyond those simply required for prioritisation and technology choices, and should also include reference to the way in which projects are implemented and managed, requirements for community involvement, requirements for supporting emerging sub-contractors, etc. Formal criteria for acceptance will presumably be identified by

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29 This is similar to the form F15 stage in the Eskom Capital Value Chain process (Table 1 of Annexure A).

the utilities and specific funding authority. However, as this final stage of funding approval is vital to ensuring that correct approaches to electrification project implementation are carried out, some attention has been given below to the development of a list of key items.

Table 8: Final project acceptance criteria for electrification projects – a proposal

	Requirement
1	**Demand and user acceptance**
1.1	The application will include a signed statement from the local authority (or other appropriate body acting as a representative of the community), to the effect that the proposed electrification plan is acceptable to the majority of households in the area.
1.2	The number of connections assumed in the analysis below should be supported by commitments from potential customers or some other indication of expected demand
2	**Financial and economic assessments**
2.1	A financial analysis from the consumer's[30] perspective should indicate that the assumed uptake rates and the assumed load growth profiles are realistic.
2.2	A financial analysis for the entire project should indicate that the operational costs will be met over the longer term. Alternatively, assurances must be given by the service provider that the operation and maintenance costs will be covered by a quantified cross-subsidy from defined sources according to an explicitly agreed policy.
2.3	The application should specify the minimum subsidy (if any) required to make the project financially feasible for the service provider.
2.4	The financial analysis should indicate the NPV of the entire project.
2.5	The application should include a risk assessment .
2.6	The application should indicate the sensitivity of the financial analysis to: • load growth rate; • uptake rate, esp. in the case of off-grid; • cost of energy; • operation and maintenance costs; • tariff or loan repayment rate; • other factors identified in risk assessment (if amenable to sensitivity analysis).
2.7	The applications should incorporate an economic analysis[31] which reports separately: • benefits as a result of household connections; • benefits as a result of community service connections (schools, clinics, etc); • benefits as a result of non-household (business) economic activities that will be affected by the project; • costs – again broken up into the above categories.
2.8	Where there is a question of technology choice, both an economic and a financial analysis should be presented for the next best technology option, and reasons motivated for the choice made if a least cost option has not been followed.
3	**Not-easily quantified costs and benefits**
3.1	The application will include comments on benefits and costs of the electrification project which have not been fully accounted for in the financial and economic analysis
4	**Maximisation of benefits**
4.1	The context of the project within the broader development framework and any other planning initiatives in the region should be articulated.

[30] Consumers from lower, middle and upper income groups should be considered. Non domestic consumers should also be considered.

[31] The economic analysis should be carried out using a standard methodology so as to facilitate comparison between projects

	Requirement
4.2	The application should indicate what opportunities for economic development have been incorporated in the proposed plan.[32]
4.3	The application should indicate what measures have been and will be taken to maximise the benefits of electrification to end users.
4.4	The application should include details of, and expected success of, measures taken to maximise demand where this is economically and environmentally efficient.[33]
5	**Community empowerment and involvement**
5.1	The application should indicate what steps have been taken to: • involve community members in the project implementation; • use community or local contractors in project implementation; • involve community members (if appropriate) in longer term project operation (vendors, maintenance).
6	**Environmental and cultural sensitivity**
6.1	The service provider should provide assurance that due consideration has been given to environmental and cultural heritage considerations in the project planning and location of equipment.[34]
7	**Capability and quality assurance**
7.1	The service provider should demonstrate that it has the necessary technical, financial, project management, community liaison capacity to undertake the project.
7.2	There should be assurance provided from the applicants that the applicable technical standards and quality assurance measures and codes will be applied. These should include reference to system performance.
7.3	There must be adequate provision and capacity for long term, sustainable maintenance (in the case of renewable energy systems, this criterion should be expanded).
8	**Public planning**
8.1	The application will indicate probable grid extension plans for at least the next five years within a 15 km radius of the project site.[35]

32 This may mean, for example, that bulk lines have been routed close to water abstraction points to facilitate installation of pumps, rather than simply following the access road.

33 For example, in Thailand, incentives were offered to facilitate conversion from diesel to electricity for shaft power requirements (Galen 1997).

34 An environmental checklist should be compiled, to ensure that all necessary considerations are checked.

35 This serves two purposes. Firstly, it facilitates assessment of possible future benefits of infrastructure being laid. It also helps to ensure that long term planning takes place, and is public

6. Recommendations for further work and concluding remarks

6.1 Recommendations for further work

Key problem areas have been identified which bedevil electrification planning in an integrated grid and off-grid environment, and the development of objective, preferably simple yes/no criteria. Some of these have been discussed in the main report (with suggestions for further work to address them). In summary:

- While there is a de facto electrification policy in place, there is no nationally agreed, electrification policy which clarifies:
  - principal objectives of electrification;
  - responsibility for integrated grid and off-grid planning;
  - minimum levels of supply.
  - Financial constraints, both to capital and to ongoing operational costs.
- Off-grid development requires information on long-term grid development plans, otherwise both communities and agencies will be reluctant to invest in technology that is not as attractive to the customer as grid electrification. In contrast, public, long-term detailed plans are not a priority for grid electrification, and there is sensitivity to the changing dynamic of rural society, which may invalidate long term planning.
- Electricity consumption growth is difficult to predict (there is ongoing work being undertaken to improve the basis for prediction).
- There is insufficient experience of the social, financial and economic costs and benefits of off-grid electrification options: at this stage it is not even certain under what financial and institutional modus operandi off-grid electrification will take place. Field experience is urgently required if off-grid electrification is to be incorporated successfully into electrification planning.

There are two significant constraints to the proper development of criteria for this project, which could be alleviated through further research work, even in the currently uncertain electrification policy environment. Firstly, detailed comparative evaluations of different off-grid technology options as against grid electrification should be carried out for a number of case studies, to give a better idea of the expected costs and benefits (social, technical and economic) of different options. These should be carried out using a uniform methodology, and using input data representative of different settlement options in South Africa. The results would be useful in their own right, informing first pass decision making and providing further quantification of criteria. The methodological approach would support the development of a standard tool for cost benefit analysis to be used for grid and off-grid electrification projects (similar to that currently used by Eskom and the DBSA for grid projects).

Secondly, there is a need to test and further develop project selection criteria through practical implementation of integrated grid/off-grid planning. In the first instance this could be carried out as an exercise for a sub-region using available data (some of which is settlement specific). Some data that can only be captured through engagement with communities will be required (for the more detailed analysis of the type discussed in section 5.6 and 5.7). This could either be collected through field research in communities (if there is a commitment to follow up with implementation of approved plans) or, less usefully, assumptions could be made based on previous research and project experience.

6.2 Closure

This paper has reviewed current selection criteria (and to a lesser extent planning processes). Recommendations have been made regarding information requirements and factors which should be considered for integrated grid and off-grid electrification planning (Table 5). Two broad approaches to project selection, prioritisation and technology choice have been presented in Chapter 5, with their associated principal criteria. These can be used as a framework, and discussion basis for the further development of selection criteria for integrated grid and off-grid electrification planning by different institutions, or a future NEF.

In summary, the 'grid prioritised' approach to decision-making assumes that grid will always be the strongly preferred option, and therefore requires that clear, long term, prioritised grid electrification plans be made publicly available and presented for open debate. 'Off-grid' areas are then identified by default as those areas not reached in the grid plans, or those areas in which the scheduled date for grid electrification is sufficiently far into the future to make interim 'off-grid' supply worthwhile.

The 'rational technology' approach assumes that rational choices can be made on the basis of technical, social and economic analysis of the technology options for given settlements. This approach is more flexible and better suited to individual project assessment. Nevertheless, it does require an either/or choice, as off-grid electrification viability is strongly negatively affected by either the perception, or the actuality of subsequent grid electrification. A rational technology choice requires that all electricity requirements in communities be carefully assessed, as there is considerable sensitivity of off-grid system design and costing to load patterns, reliability requirements and load factors. It is also important to ensure that costs and benefits are referenced to a common base – that is, the full costs including generation externalities should be included in assessments.

Both approaches require that preliminary categorisation of communities into *'grid'*, *'off-grid'* and an *'uncertain'* area be carried out- primarily through the use of GIS systems using data that is generally available (or soon will be).

There is inevitably a significant emphasis on careful financial and economic analysis of possible projects, particularly in the 'uncertain' region. These will require information-gathering on settlement-specific conditions, especially relating to indicators of expected consumption, affordability and willingness to pay. However the need to explicitly include other factors, some of which influence financial and economic analysis, is noted. Perhaps most important here is attention to integration of electrification planning with other initiatives.

Finally, a separate set of conditions which projects should satisfy before implementation goes ahead has also been listed. The emphasis here is not so much on choosing whether a community should be electrified using grid or off-grid technology, or even on determining priority, but rather on identifying key factors which should be checked to ensure that projects have the best opportunity of success and maximisation of benefit.

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Annex A:
Summary of criteria for operational decision-making

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Table of contents

Introductory note

The recommendations regarding criteria developed in Banks (1998) have been summarised here for ease of reference. The reader is however cautioned. As a summary of a complex field, this annex is by nature incomplete. Process is an important component of decision making, and space does not permit presentation of the process here. Of particular concern in presenting the summary, is that involvement of communities and different levels of decision-makers in the process is not adequately reflected. Chapter 5 of Banks (1998) provides a more considered rationale and contextualisation of criteria within the planning process.

1 Criteria for 'first pass' decision making

Decision making will take place in a number of stages. The first is to allocate settlements to one of three categories:

- those where **grid** electrification is definitely the preferred option;
- those where **off-grid** technologies are readily identified as being more appropriate (remote, small communities);
- and an **uncertain** area for which decisions are not as readily made.

Categorisation into these three areas can be achieved relatively easily using readily available data, preferably using a GIS data management system. The **uncertain area** should be large enough such that few settlements are incorrectly placed into the **grid** or **off-grid** area. Criteria to be used are:

1. Indicators of lower cost:

- settlement size
- proximity of households to each other (density)
- distance between settlements of similar size (or if closer to the nearest grid line)

2. Indicators of greater potential benefit from electrification

- number and location of public facilities such as clinics and schools
- existence (or not) of significant business and/or agricultural development
- income or other wealth related data

- knowledge of related development plans in other sectors (integrated development)
- site specific opportunities for economic benefit

2 Criteria to be used to narrow the 'uncertain band'

Two approaches are suggested, depending on the circumstances. In a regional planning exercise, it is recommended that the **grid prioritised** approach be followed. For individual project level decision it will sometimes be more appropriate to use the **rational technology** selection approach. The approaches are illustrated in figures 1 and 2.

Note: in both cases more detailed analysis and information is required compared to the above 'first pass' decision processes. However, the focus here is only on the settlements that are more difficult to prioritise. Such detailed work will not be required for all settlements.

Figure 1: Grid prioritised sub-regional planning

Key principles and assumptions

- Grid connection is the strongly preferred option for a variety of reasons (not all readily quantified).
- Accept that economic, financial and social benefits analysis is adequate to prioritise projects which deliver comparable benefits (at least in the first instance).
- Acknowledge that economic analysis is a relatively blunt instrument to rank options that deliver significantly different benefits (i.e. that 20 A grid vs. off-grid decisions cannot easily be made on the basis of techno-economic analysis, particularly in borderline cases).
- As a result, off-grid areas are defined primarily a result of carefully prioritised long term grid planning, carried out in the context of a defined financial and institutional grid electrification resource.

Steps in the planning process

Process	*Criteria*
Step 1: Identify areas/settlements/hh of region where grid is definitely not viable during planning period (say 7 years).	Estimated cost of grid electrification above agreed maximum (y Rands per connection) Indicators: Large distances between households and/or settlements, small settlement sizes, low wealth index, few public facilities.
Step 2: For remainder of region, carry out grid plan based on agreed ADMD for hh. Include known community and commercial loads.	Best practice electrification and network planning (70% level of certainty).
Step 3: Review plan to identify and remove from grid plan areas and hh which are too expensive.	Cost per connection higher than maximum (as for step 1).
Step 4: Rank all remaining electrification projects in order of priority for electrification.	• Financial NPV • Economic NPV or CBA • Modified as follows: • Social service given high priority • Consideration of other development initiatives
Step 5: Use the ranking to develop possible electrification programme plans with approximate dates of project implementation.	Different plans would be generated using the information from steps 3 and 4, depending on the level of resources allocated to grid electrification.

For each grid plan, there will be an implied complementary identification of off-grid areas. This will comprise those areas identified in steps 1,and 3, as well as those which do not rank sufficiently high on the priority list (step 4) to be connected within the planning time and budget schedule (step 5).

Step 6: Select a grid electrification plan.	• Balancing resource allocation to grid and/off-grid. • Coverage vs. economic benefit.
Step 7: Publish, and discuss Allow for reprioritisation.	Reprioritisation must be supported by financial input from non-NEF sources if it has financial implications.

Figure 2: 'Rational technology' selection approach

In the more critical borderline cases, a careful technology choice is made, rather than allowing the grid/off-grid decisions to be essentially a by product of a grid planning exercise. This approach requires:

- An accurate social, technical and economic evaluation of grid / off-grid costs and benefits which has a sufficient level of confidence to allow robust grid/off-grid decisions.
- In order to improve decision making accuracy, it is recommended that thermal needs (and energy supply options that meet these needs) be included in the evaluation.

Process	*Criteria*
Step 1: Identify areas/settlements/hh in region which are readily allocated to grid planning priority.	Estimated cost of grid electrification below agreed minimum. Key indicators: Large settlements, settlements close to each other, close to existing grid High economic potential, public facilities require grid.
Step 2: identify areas/settlements/hh in region which are easily allocated to off-grid plans.	Estimated cost of grid electrification above agreed maximum, or equivalent service can be supplied at lower life cycle cost. Indicators: Small settlements, large distances between households and /or between settlements.
Step 3: Design and assess costs of supply for borderline settlements/clusters of settlements. Consider all potentially viable technologies.	Best practice planning for each technology Must include all potentially viable loads
Step 4: Make technology selection Assign settlement to technology specific planning process.	Financial analysis Economic analysis Tools must be fair and consistent across technologies (i.e. include portion of total grid infrastructure costs, and externalities). Include thermal energy needs in evaluation.
Step 5a: Rank grid projects and develop implementation schedule **Step 5b:** Rank off-grid projects and develop implementation schedule.	Technology specific planning and prioritisation criteria. Schedule should use available budget allocations. Consistency not required across technologies
Step 6: Consult and allow influence of decision by communities (subject to criteria).	Community access to additional funding. Redefinition of priorities within settlement
Step 7: Assess implications of the assumed budget allocations to the grid and off-grid programmes.	Balancing resource allocation to grid and/off-grid Coverage vs. economic benefit
Step 8: Publish and discuss, allow for reprioritisation.	Reprioritisation must be supported by financial input from non-NEF sources if it has financial implications.

2.1 Grid prioritised approach

2.1.1 Information required

- Estimated capital cost of grid electrification with a level of certainty of approximately 70%
- Number of permanent households and population in settlement
- Percentage of households in community that would be electrified
- Assessment of the number and scale of business activities in the community
- Status and number of schools and clinics in or close to settlements
- Identified specific opportunities for extra benefits from electrification (e.g. water supply, agricultural development, specific entrepreneurial activities)
- Wealth or preferably better indication of expected consumption and willingness to pay
  - woodfuel scarcity or strong commercial woodfuel market indicating high priority for thermal applications
  - regional information on technical and non-technical losses

2.1.2 Prioritisation

Using the above settlement specific information, settlements should be prioritised for grid electrification using in the first instance:

- financial analysis
- economic analysis

The choice of whether to place primary emphasis on the financial or economic analysis will depend in part on the electrification strategy and policy adopted (see main report for discussion).

Note: Financial and economic analyses are already carried out as part of the electrification planning process. The above does not present significant departure from the status quo, except that greater emphasis is placed on gathering settlement specific data, and on incorporating business and social services more fully.

2.1.3 Adjustments to prioritisation

Adjustments to the prioritisation list should be made on the basis of the following:

1. Settlements which are of significant importance (relative to others) in the region, should be moved up the priority list. These can be identified through the following indicators:
   - settlement size;
   - presence of schools, health facilities, and public administration offices;
   - location with respect to important transportation routes.

   (Note that, in both cases, the economic analysis will have accounted for this in some measure already, and it is thus not clear that ranking should be altered on these grounds).

2. Planning authorities should actively engage with other planning and development initiatives in the region, to share and gather information. Of particular importance would be 'Development Corridors' and 'Spatial Development Initiatives'. Settlements that are likely to contribute to, or benefit from, these planned initiatives should move up the priority list. Due cognisance should be taken of appropriate project scheduling.

3. Settlements which have inadequate water supply, or for other reasons are not viable as permanent places of residence, should be moved down the priority list, unless defined plans

are in place to improve the situation. If supply of the grid will contribute to this improvement, then this should be included in the economic analysis.

4. This review of the priority listings should be carried out with the aid of area maps, which show the relationship of settlements to each other, and to the major proposed grid extension routes. Due cognisance will have to be taken of the interdependence of specific settlement project viability on the electrification of nearby settlements.

2.2 Rational Technology based decisions

Criteria used for an explicit comparison of technologies would be similar to those described above, with the following additional points noted.

- The capital and life costs of grid (and off-grid) technology used in the financial and economic analysis should include:
    - externalities on the generation side (costs);
    - health and related externalities on the customers side (generally benefits);
    - the full costs of grid extension should be factored in (including a share of bulk supply); however, as for the grid prioritised approach, sharing of bulk supply costs between different settlements should be applied;
    - the effect of the peaky nature of domestic loads on the cost of electricity supply should be included in the analysis
- Economic opportunities (and constraints resulting from supply choice) should be reviewed and included in the analysis.
- Given certain off-grid technology's considerable cost sensitivity to load magnitude and load factor, it will be necessary to identify all significant loads, and include these in the preliminary design and analysis (water pumping, health centre, schools, SMME requirements).
- As grid technology has the potential to meet some thermal needs, but off-grid technology usually does not, it is recommended that the costs and benefits of energy for thermal energy needs be included in the analysis.

Again there are important, as yet unresolved concerns regarding placement of emphasis on financial or economic analysis. Please refer to the main report for discussion of this.

3 Criteria for final project acceptance

The above criteria would be primarily used in the planning process. The following table presents a proposal for criteria to be used for final project acceptance by funding authorities.

Table 1: Final project acceptance criteria for electrification projects – a proposal

	Requirement
1	**Demand and user acceptance**
1.1	The application will include a signed statement from the local authority (or other appropriate body acting as a representative of the community), to the effect that the proposed electrification plan is acceptable to the majority of households in the area.
1.2	The number of connections assumed in the analysis below should be supported by commitments from potential customers or some other indication of expected demand
2	**Financial and economic assessments**
2.1	A financial analysis from the consumer's[1] perspective should indicate that the assumed uptake rates and the assumed load growth profiles are realistic.
2.2	A financial analysis for the entire project should indicate that the operational costs will be met over the longer term. Alternatively, assurances must be given by the service provider that the operation and maintenance costs will be covered by a quantified cross-subsidy from defined sources according to an explicitly agreed policy.
2.3	The application should specify the minimum subsidy (if any) required to make the project financially feasible for the service provider.
2.4	The financial analysis should indicate the NPV of the entire project.
2.5	The application should include a risk assessment .
2.6	The application should indicate the sensitivity of the financial analysis to: • load growth rate; • uptake rate, esp. in the case of off-grid; • cost of energy; • operation and maintenance costs; • tariff or loan repayment rate; • other factors identified in risk assessment (if amenable to sensitivity analysis).
2.7	The applications should incorporate an economic analysis[2] which reports separately: • benefits as a result of household connections; • benefits as a result of community service connections (schools, clinics, etc); • benefits as a result of non-household (business) economic activities that will be affected by the project; • costs – again broken up into the above categories.
2.8	Where there is a question of technology choice, both an economic and a financial analysis should be presented for the next best technology option, and reasons motivated for the choice made if a least cost option has not been followed.
3	**Not-easily quantified costs and benefits**
3.1	The application will include comments on benefits and costs of the electrification project which have not been fully accounted for in the financial and economic analysis
4	**Maximisation of benefits**
4.1	The context of the project within the broader development framework and any other planning initiatives in the region should be articulated.

1 Consumers from lower, middle and upper income groups should be considered. Non domestic consumers should also be considered.

2 The economic analysis should be carried out using a standard methodology so as to facilitate comparison between projects

	Requirement
4.2	The application should indicate what opportunities for economic development have been incorporated in the proposed plan.[3]
4.3	The application should indicate what measures have been and will be taken to maximise the benefits of electrification to end users.
4.4	The application should include details of, and expected success of, measures taken to maximise demand where this is economically and environmentally efficient.
5	**Community empowerment and involvement**
5.1	The application should indicate what steps have been taken to: • involve community members in the project implementation; • use community or local contractors in project implementation; • involve community members (if appropriate) in longer term project operation (vendors, maintenance).
6	**Environmental and cultural sensitivity**
6.1	The service provider should provide assurance that due consideration has been given to environmental and cultural heritage considerations in the project planning and location of equipment.[4]
7	**Capability and quality assurance**
7.1	The service provider should demonstrate that it has the necessary technical, financial, project management, community liaison capacity to undertake the project.
7.2	There should be assurance provided from the applicants that the applicable technical standards and quality assurance measures and codes will be applied. These should include reference to system performance.
7.3	There must be adequate provision and capacity for long term, sustainable maintenance (in the case of renewable energy systems, this criterion should be expanded).
8	**Public planning**
8.1	The application will indicate probable grid extension plans for at least the next five years within a 15 km radius of the project site.[5]

References

Banks, D I, 1998. Criteria to support project identification in the context of integrated grid and off-grid electrification planning. Energy and Development Research Centre, University of Cape Town.

[3] This may mean, for example, that bulk lines have been routed close to water abstraction points to facilitate installation of pumps, rather than simply following the access road.

[4] An environmental checklist should be compiled, to ensure that all necessary considerations are checked.

[5] This serves two purposes. Firstly, it facilitates assessment of possible future benefits of infrastructure being laid. It also helps to ensure that long term planning takes place, and is public

Annex B:
Notes on electrification decision making practice in South Africa

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March 1998

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Table of contents

List of Tables

1. Introduction

This annexure is intended to provide an overview of current electrification decision making processes, and to identify and list the criteria being used. The material should be seen as a set of edited research notes, which support the material presented in the main report. It is not a formal review of criteria.

A number of information sources were used in compiling this review. These included presentations and discussions held at two project workshops, telephone or face to face interviews with selected personnel from different institutions, and review of documentation in reports, papers and planning manuals.

2. Eskom electrification issues and criteria

2.1 Grid electrification planning process

The Eskom electrification planning process is primarily focused around the objective of achieving the agreed NEES Electrification targets using considerable, but finite financial resources. The process is structured, and there is a formal planning process. National and regional targets are set, and within this individual projects must pass through a series of planning stages as described in the Capital Projects Value Chain (see **Table 1**). Formal checking processes are required before projects can progress from one stage to the next, with the Capital Investments Committee being the formal decision-making authority within Eskom. Such a structured process clearly allows formal decision-making process and criteria. However there is also room for less structured decision making, particularly at the early stages of the process, when field officers decide whether or not to include settlements in the initial planning process.

The five-stage project planning process clearly has to mesh with, and is integrally affected by, larger regional and national planning processes.

2.2 Regional allocation

The national target, as noted above, is set according to the NEES mid level scenario, and as documented in the RDP plan. Annual programme budgets are set by Eskom's internal capital budget process, based on an assessment both of available Eskom resources, and costs of projects provided by regional planning processes.

Financial allocations to regions are based primarily on the percentage of unelectrified households in the areas, and the costs of connections expected in the areas. These two are balanced in an effort to achieve the targets within the allowable budget, and to achieve reasonable regional equity. See Thom (1998) for further information.

2.3 Settlement identification within regions

Settlement planning is primarily co-ordinated through the Electrification Planning Managers in the regional offices, and the regional planning staff at the SACS sub-regions. A five-stage process is followed, as outlined in **Table 1** below. Details of the process are supplied in Module 6 of Eskom (1995).

Table 1 Eskom Planning process outline

Planning process	*Key role players*	*Principal criteria used*
First stage (F1) Identification of site for advance planning	Community- application Eskom regional district office staff	Proximity of households to each other (density) Terrain, distance from grid Network capacity perceived economic activity in area Levels of migration
Second stage (F10) Develop plan including numbers and cost per connection	Consultants and land surveyors instructed by Eskom staff, sometimes Eskom staff used. Submitted to Capital Investment Committee	Cost per connection Number of dwellings to be connected
Third stage(F15) Includes design and layout of grid, 90% accuracy for task, Estimate returns on capital	Consultants Submitted to Capital Investment Committee for final approval	Cost per connection Number of dwellings to be connected In principle: financial and economic analysis using Eskom/DBSA CBA model
Fourth stage F150 Final tender documentation and appointment of main contractor (or in house team). Execution of project	Consultant Engineer Main Contractor LV reticulation usually awarded to several small contractors on nominated basis under supervision of Consultant Engineer Project Marketing and signing up carried out by Eskom Sales and Customer Services	
Fifth Stage (F101) Establishment of as built costs Closure of contracts Switching on	Various	

Sources: Van Gass 1997, Annecke *et al* 1998, Eskom 1995, Discussions with Gwala, Nell, Gerstner (1997)

Electrification project identification takes place in a number of ways, as listed below (James 1996; Eskom 1995):

- Community groupings, individuals, or politicians approach Eskom to request electrification of specific settlements. In some regions (particularly the Northern Province) electrification forums play an important role.
- Database information on settlement size, location, and some socio-economic indicators is used for identification, and to assist in the evaluation of all possible sites.
- SACS staff visit areas, and through visual assessments, brief interviews with a few residents and based on their experience, make assessments of possible areas. Such identification could frequently be applied to settlements in close proximity to existing projects, or to subsequent phases of existing projects, supported by the lower resultant costs of extending the network infrastructure.
- Recently (Gerstner 1997, Eastern Cape, Nell 1997, Northern regions, and Gwala 1997, KwaZulu-Natal), the planning staff have been able to utilise the HELP

database/GIS to a greater extent. This has reduced the need for staff to spend time in the field, and has allowed a more desk based planning approach. Planning processes have thus become a little more rational, and Gerstner expects less pressure from communities seeking to influence the priorities.

2.3.1 Criteria used for settlement electrification planning and decisions.

Categories of planning criteria used by Eskom in the selection and prioritisation of settlements include:

- network availability and expansion requirements;
- capital costs of electrification;
- expected financial return;
- expected economic return;
- socio-economic factors including an assessment of community demands, equity, demographic movement;
- environmental criteria;
- (in some cases) political influences.

2.3.2 Network availability

Three factors are important here:

1. What is the proximity of the proposed electrification project to the existing grid? This will influence the cost of line extension work required to get electricity to the area in question.
2. Is the existing grid capacity adequate to cope with the additional demand placed on it by the new electrification project? This will require an assessment of the peak demand likely to be handled by the electrification project, as well as an assessment of the current available unutilised capacity on the grid network. Sophisticated network design tools are available to facilitate the technical component of this review. However, a considerable area of difficulty, is in establishing what the demand growth will be (either in the new project) or in other projects which rely on the same grid feeder line.
3. If upgrading is required, how will costs be apportioned to the new project, and to other areas that will also benefit from the upgraded line? This question complicates electrification planning financial allocations in a variety of ways. What portion of expenditure should be allocated to different customers?

Eskom does have a separate budget which is used for general network upgrading, or for specific development of the network in specified areas. The relationship between this budget and the electrification budget has not been adequately explored as part of this work. However, from discussions with Eskom planning staff, it is apparent that the decisions made by the network planning group can have a profound impact on the capital costs apportioned to subsequent settlement electrification projects, and hence on settlement prioritisation and selection.

2.3.3 Capital cost per connection

Given the limited capital budgets allocated to regions, the capital cost per connection provides an important constraint to electrification planning. Recent discussions with Eskom staff (Bopela 1997; Stephen 1997; Maré 1997) have confirmed that capital cost is the most important criterion being applied at present at a local level. There are some exceptions to least cost planning, in cases where significant political pressure is applied to influence Eskom planning.

Note that the capital cost limits for different regions are not all equal. There is acknowledgement of the significant variation in costs experienced in different parts of the country. This allows planning mangers within these regions to balance more expensive projects with lower cost projects, provided that they can arrive at an acceptable average figure for the region.

The capital cost per connection is made up of a number of components, as listed in **Table 2** below. The principal factors that influence the costs are also listed.

Table 2 Factors which influence the cost of electrification

Item	*Typical costs*[1]	*Factors which influence costs*
Connection at household	R898 (24%)	▪ Pre-payment more expensive than credit metering. Unmetered (2.5 A) connection the cheapest. ▪ Marginal reduction of costs per connection for larger projects. ▪ Household structure (are kicker poles required or is wall strong enough that cable can be attached directly to wall) ▪ Costs have reduced over last few years.
Low voltage reticulation	R2265 (60%)	▪ Density of households- costs reduce as the number of households connected per km of reticulation line decreases ▪ Terrain – hilly or rocky terrain can increase costs ▪ Material choice ▪ Design After Diversity Maximum Demand (ADMD)
MV-LV transformers	Included in above LV reticulation cost.	▪ Medium voltage rating ▪ Load factor ▪ Peak demand ▪ Density of households – no of connections that can be served by one transformer ▪ Design ADMD
Medium voltage local distribution	R235 (5%)	▪ Density of households, distance between clusters
Medium voltage grid extension	R131 (4%)	▪ Distance from existing grid infrastructure ▪ No. of hh to be electrified per km of grid extension ▪ Terrain over which lines must be built ▪ Number of settlements which can benefit – clustering ▪ Design ADMD ▪ Load factor
High voltage bulk supply line (Not always required)	R292 (8%)	▪ Distance ▪ Capacity of existing infrastructure – does it need to be upgraded ▪ Number of settlements which can benefit – clustering potential ▪ Design ADMD
HV-MV substation (Not always required)	Included in figure above for MV substation	▪ Peak demand ▪ Load factor
Labour and consultants fees	Included in above costs	▪ Local, contractor, or Eskom staff ▪ Clustering of projects to reduce travel and establishment costs ▪ Productivity

[1] These figures are illustrative only. They are the average percentages of the costs presented in table 6.1 of Davis and Horvei. 1995 and are thus derived from the initial phases of the electrification programme. As the remaining settlements to be electrified become more remote and smaller, the costs of line extension and LV reticulation become more and more significant.

Eskom, and consultants have developed design tools to assist in electrification design and costing. These range from experience-based approximate costing methods such as those described below, to sophisticated spreadsheet based design tools which have detailed cost data for different components. Some design tools incorporate algorithms to assist the designer to choose the optimum technology option (an example of such a spreadsheet based tool is the Electrification Technology Cost Estimator Programme developed by Eskom).

Since accurate detailed costing is relatively time-consuming and expensive to carry out, it is necessary to use indicators of expected cost during planning and preliminary assessment processes. The major indicators are discussed in further detail below, as they suggest the data needs, and the expertise and computation levels required in order to estimate preliminary cost information for decision processes. The indicators also serve to illustrate the sensitivity of electrification costs to key variables such as density and distance from supply point.

2.3.3.1 Settlement density

Eskom personnel have explored the relationship between household density and cost of reticulation infrastructure in some depth. Table 3 is based on a set of rough indicators drawn up for the Northern distributor, where households tend be located in a relatively formal grid layout.

Table 3 Summarised cost per connection for reticulation – indicators only

Category	*No. connections per km²*	*Cost per con. (Rands)*
Urban (1)	>1662	1520
Urban (2)	823-1662	1345
Peri Urban (1)	339 – 822	1775
Peri-Urban (2)	160 – 338	1980
Rural	84-167	2740
Deep Rural	< 83	3400

Source: Nell (1997)

Gerstner (1997) noted that settlement densities that would allow 150 potential connections per square kilometre are required to meet the cost per connection targets in the Eastern Cape. In the former Transkei, densities range from 70 to 200 households per square km, with relatively few at densities above 150 households/km. In contrast average densities of 200 hh/km² in the Ciskei mean that lower cost options can be followed there.

In KwaZulu/Natal, Gwala (1997) noted that a household density of 70 hh/km² is required to meet capital cost restrictions if significant grid extension is *not* required.

Stephen (1997) and Geldenhuys (1997) however note that household density is not always useful as an indicator of cost in certain regions of the country such as KwaZulu/Natal and parts of Transkei, where households are grouped in small isolated clusters. This problem has been exacerbated by the gradual reduction in the household density at project sites, as the grid extends further into marginal areas. Stephen (1997a) has found the cost per connection to be more accurately correlated with the number of households per km of reticulation line. This method of preliminary cost estimation requires that the length of MV grid and the length of LV line required be estimated and divided by the total number of connections, to yield a ratio (connections per km). Stephen uses an exponential correlation equation to determine estimated costs per connection.

Both the density measure, and Stephen's method of estimating costs based on connections per km of line are intended only to serve as preliminary indicators of cost prior to more detailed analysis being carried out. They would thus be used in first level analysis only.

2.3.3.2 *Distance from existing grid and settlement size*

As noted in **Table 2**, the average contribution of bulk supply to electrification costs was of the order of 12% in 1995. There are however significant regional variations, depending on the status of the grid infrastructure in the regions. High voltage bulk supply lines cost of the order of R400 000 km for 132 kV lines. These are not generally required for single settlements, but rather form part of the electricity grid back-bone. The costs are however extremely high, and if a portion must be funded from electrification project budgets, can significantly affect capital costs.

More commonly required are medium voltage (MV, 22, 33 or 66 kV) lines. Stephen (1997b) recommends an average cost R53 000 per km, including transformer structures (excluding the costs of the transformers). Costs for the lines only vary from R 7000 /km for a low kVA SWER line to R55 000 for a three-phase system with relatively high current capacity (360 A per conductor) (Stephen 1997b). The costs of line extension (and transformers) are not directly proportional to the total load. Thus the contribution of line extension costs to the average cost per connection for a given extension distance reduces as the number of households connected increases. Smaller communities are therefore more expensive to electrify. Similarly, if only a small portion of a larger community is electrified, the costs per connection will be increased.[2]

2.3.3.3 *Clustering of settlements*

If a number of settlements can be electrified in a reasonably small geographical region, then savings can be achieved not only through shared use of transmission lines, but also through lowered logistical costs in that travel and establishment costs for marketing, materials supply, construction and installation can be reduced.

Important in this regard is the impact that electrification of one community can have on the future electrification costs of a nearby community, if the bulk supply lines have sufficient capacity. This means that costs for such bulk extension should not all be allocated to the first project, but should be apportioned between current projects and projects to be completed in the future. Mechanisms for doing this have not been identified.

2.3.3.4 *Technology choice*

A number of technical choices influence the costs of connection, and thus the prioritisation or possible exclusion of a project from implementation. Three principal areas of choice have been identified:

- Bulk and reticulation capacity, based on the expected ADMD
- Load limited or prepayment meter options for supply
- MV bulk supply and reticulation. Single Wire Earth Return (SWER) technology can significantly reduce costs.

The principal area where criteria are required for grid electrification is the design capacity of the transmission lines and reticulation network, in order to cater for the expected After Diversity Maximum Demand (ADMD). This is very closely related to the issues discussed in section 4.4.2 of the main report.

Geldenhuys (1996) has modelled electrification costs for a cluster of four settlements of 500 households each, located 20 km from the existing grid. The lowest cost 2.5 A limited-current supply option (using SWER) is 33% less than the more conventional 20A prepayment meter system. A major contribution to this reduction in cost is the lower capacity of transmission lines and transformers which can be installed given the cap on individual consumption imposed if 2.5 A connections are utilised in a settlement.

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[2] James (1996: 5) notes that prioritisation processes carried out with electrification forums in the Northern Province and Mpumalanga sometimes resulted in small portions of communities being electrified (inefficient), the objective being 'fair' distribution of connections between settlements.

Quality of supply is also an important technical issue which can have significant effects on the cost of supplying electricity. If the allowable voltage drop is increased, then it is possible to use lower cost lines for reticulation, especially to more remote houses. Furthermore, if occasional power outages or load shedding as a form of peak management are tolerated, then it is possible o implement significant savings.

2.3.3.5 Financial and economic analysis

Eskom and the DBSA utilise a shared economic analysis model. The current version has a been extended from a base developed by EDRC and documented in Davis and Horvei 1995. Subject to certain qualification regarding the reliability and appropriateness of data used (see section 4.4 of main document), the tool does provide a useful indication of project financial viability (from the utility perspective), and of the potential economic costs and benefits to society as a whole. Typical output of the model and guideline project requirements are listed in **Table 4**. In principle, project approval is only for projects which have a positive financial NPV, and an economic internal rate of return greater than 6%. While the latter condition is frequently met, the financial NPV is seldom greater than zero.

The CBA tool is primarily used by Eskom as a project acceptance/rejection criteria, rather than being used as one of the inputs to for prioritisation.

Table 4: Typical CBA model results

Financial results:	*(LRMC)*	*(SRMC)*	*Requirement*
Net present value (R '000):	(R1 910)	(R2 223)	NPV > 0
Net present value/customer:	(R2 011)	(R2 340)	NPV ≥ 0
Internal rate of return:	6.8%	3.2%	IRR ≥ 15.5%
Cross-subsidy required:	5.2 c/kWh or R7.18 per customer /month		
Economic results:	*Ave costs (LRMC)*	*Marginal (SRMC)*	*Requirement*
Net present value (R '000):	R865	R547	NPV > 0
Net present value/customer:	R910	R576	NPV ≥ 0
Internal rate of return:	9.6%	8.5%	EIRR ≥ 6%
Benefit to cost ratio:	1.23	1.13	BCR ≥ 1

2.3.4 Socio-economic factors considered in the electrification planning process

James (1996) lists a number of other criteria that are considered in settlement prioritisation by Eskom. These include:

- the status of existing infrastructure in the area (roads, telephones, buildings);
- other development initiatives in the area;
- the availability of water;
- dwelling types (referred to above);
- the existence or otherwise of clinics and schools;
- population;
- migration patterns.

There are also factors that may influence household consumption such as:

- fuel expenditure patterns.
- income levels (with an implied link to demand profiles).

These and similar factors are also referenced in a number of Eskom documents on electrification planning (Eskom 1995; Focaraccio *et al* 1997; Focaraccio & Gerstner 1997). It is however not yet clear to what extent these considerations have been articulated as criteria, and incorporated into planning practice. Recent discussions with Eskom personnel have indicated that least cost (capital) has become the overriding criterion for project approval and prioritisation.

Key criteria are discussed in more detail below.

2.3.4.1 *Integrated planning*

The importance of integrated planning, is clearly acknowledged by Eskom. The planning manual (Eskom 1995) notes that the electrification does not automatically stimulate growth. Documents on the integration of electrification and development planning have been prepared for at least two provinces (Free State and Eastern Cape, see Focaraccio *et al* 1997, and Focaraccio & Gerstner 1997). However, the authors of these documents note that future development planning is not adequately considered in the development of electrification projects. Such consideration is clearly difficult, for a number of reasons. These include:

- Disparate responsibility for different planning functions
- Lack of information or certainty regarding existing project timing (Focarracio and Gerstner 1997)
- Delays in the establishment of infrastructure planning forums by government
- A tendency for communities to focus on one service at a time in seeking to meet their needs (Focaraccio and Gerstner 1997)

Focaraccio puts the issue succinctly:

> A holistic and integrated approach to rural development is required to address the current problems and to cultivate opportunities in rural areas. All RDP projects (Water, Housing Electrification, Schools) are planned independently by various Government Departments, Eskom and consultants and only once the projects are due to commence will some consultation take place. None of these plans are used to evaluate future projects. The elements of development that complement one another should be linked to ensure that the greatest possible synergistic effect is achieved. Only when electrification forms part of a broader initiative to achieve development objectives, and is properly co-ordinated with other inputs, can it play a meaningful role in the development of rural areas.
>
> Eskom can play an important role by taking the initiative to discuss integration of activities with other stakeholders.

In case study work carried out for the EDRC Rural Electrification Policy Research Project, Van Gass (1997) argues that Eskom does not make adequate provision for co-ordination of electrification with other development strategies. Consultants with whom Van Gass met also indicated that there were no means available to facilitate engagement of electrification planning with future development planning of other infrastructure. Nell (1997), working in the northern region, pointed out the difficulties inherent in trying to take cognisance of development planning, given the lack of clear development planning process and activity at regional level.

Focaraccio *et al* (1997: 24), on the other hand do quote some examples of successful integration of planning initiatives:

> The integration of water and electricity projects are a high priority especially in the Southern Free State District. In this district a total of 23 electrification and water projects will be executed in conjunction with one another.

2.3.4.2 *Community consultation*

Community engagement and empowerment is emphasised as an important part of the electrification process, and guidelines for consultation have been prepared (Eskom 1995). However, Van Gass (1997), reporting on two case studies in KwaZulu/Natal, notes that Eskom staff and planning consultants tend to avoid unnecessary consultation with communities prior to a decision being made to electrify the community, in an effort to reduce subsequent problems as a result of raised expectations. Consultant engineers mentioned that they were aware of sociopolitical issues, but felt that engagement in these was beyond the scope of their professional commitments. Mkhize, cited in Annecke *et al* (1998) emphasises the lack of development committees in communities as one of the six salient issues in rural electrification.

Practice does vary within Eskom, and there have been cases involving significant community level negotiation. Van der Walt (1995) noted that negotiation of electrification priorities was used successfully in the Free State.

Raised expectations can lead to severe difficulties for Eskom staff, and communities, if electrification does not go ahead in a community after preliminary negotiations and investigations. On the other hand, opportunities for creative suggestions by communities, and prioritisation according to community needs are missed if such communication does not take place.

Most significantly, if communities do not 'own' projects, there is a greater chance of difficulties such as non-technical losses, non-payment. In the case of off-grid project the problems are even more severe, with theft, abuse of systems through poor load management, and lack of system maintenance by users all being problems that can be exacerbated through poor community involvement.

2.3.4.3 Expected demand and willingness to pay

Many of the above criteria, and particularly those that relate to capital cost of connection, relate to immediate needs, priorities and pressures. However, one of the key elements of sustainability of an electrification programme, is the expected level of electricity sales, and the ability and willingness of communities to pay for the electricity service. From the utility's perspective, it is important to identify regions were the demand will be adequate to ensure a reasonable return on investment, or at the minimum to cover operational costs. Load prediction is also vital to efficient least-cost technical design.

Demand is assessed in a number of ways by Eskom staff:

- Income and/or expenditure data from databases such as the HELP database.
- Information from the *A to Z – The Decision Makers Encyclopaedia Of The South African Consumer Market* (Eskom 1996) can also be used to gather expenditure and income data, which can then be related (usually in the form of guesstimates) to expected demand.

Van Gass (1997: 5) indicates that very generalised data is processed using computer programmes to calculate demand from typical figures. Differentiation of poverty levels within regions or across communities is not included in the generalised process. These generated figures tend to be modified on the basis of informal socio-economic reviews carried out by local planners who assess the following factors:

- stability of the areas (population movement);
- wealth in the area (guesstimates);
- expected electricity use (based on limited experience);
- growth potential for electricity uptake and use (no indication of method used);
- technical losses and theft (no indication of method used).

As electrification experience deepens, load growth research such as that being carried out by Lawrence (1997), Dekenah (1997) and Davis (1995) will hopefully lead to an improvement in the situation.

Consumption growth and willingness to pay are discussed in further detail in the main report.

2.3.5 Environmental criteria

The environmental impact of grid electrification is generally not considered to be a major problem area (at the transmission and distribution end). Eskom does have a well defined environmental policy, and has on occasion gone to considerable length to minimise damage to wildlife, and in certain cases vistas, through careful pole or routing design.

In KwaZulu/Natal, (and presumably other regions) the consultants employed to carry out project planning complete an environmental checklist. This is used to avoid sacred sites and possible damage to water resources and crop resources (Van Gass 1997).

One the other hand, topographical and vegetation conditions can have a significant effect on grid extension costs, and on the costs of reticulation. Such conditions have little influence on stand alone off-grid installations. There are however significant regional differences in renewable energy resource base, linked primarily to climatic conditions (solar radiation, wind resources, water precipitation rates), and local topographical conditions (wind, micro-hydro).

Environmental externalities which result from the generation of electricity are not considered in this report, except with reference to the economic analysis of the cost of supply in the CBA models.

2.3.6 Political criteria

Van Gass (1997) notes that Eskom planners and contractors consciously limit contact with proposed electricity customers during planning stages. The principal reason given for this is to avoid raising expectations of supply prior to approval of electrification projects. Officials note that social and political difficulties arise in areas where the technical and cost based determinants of access are unacceptable to consumers.

Van Gass also notes that there may be conflicting, and opposing views within a community regarding the desirability of otherwise of particular electrification projects.

Annecke *et al* (1998), quoting an Eskom official, notes that Eskom "try and use electrification as a binding force among people". Where areas of different political affiliation lie close together, and within a single electrification project, equitable exclusion and inclusion of homesteads within the two areas provides an important example of fairness, and helps to neutralise allegations of Eskom partiality.

In KwaZulu/Natal, where settlements are often dispersed, van Gass (1997) notes that the Chief's home is often spatially separated from others in the community. While consultants are pressurised to include these lonely homesteads in planning, Eskom tends to underplay the role of the Chief, and direct engagement is avoided. It is not clear that this is a general trend.

There have been cases of high level political pressure being placed on Eskom planning staff for specific settlements to be included. Eskom staff in the Eastern Cape and KwaZulu/Natal indicate that such influences have affected planning of one or two settlements per region per year.

2.3.7 Equity

Van Gass (1997: 3) indicates that there are no defined criteria regarding an equitable geographical spread of electrification projects. However, in discussions with senior Eskom planning staff, Banks and Thom were informed that there is a level of sensitivity to the 'political heat', which influences regional and sub-regional planing allocations. See Thom (1998) for further discussion of equity considerations in regional resource allocation, where this issue is very important.

2.3.8 Supportive activities: SMME Department

The Eskom SMME Department was set up 'to augment the level of economic activity and electricity consumption in newly electrified areas' (quoted in Rogerson 1997), thus aiming to increase the potential for financial viability of the electrification programme. The department is active, in seeking out business opportunities during pre-electrification investigations and during electrification (Borchers & Hofmeyr 1997). It is however not clear that SMME activities are specifically incorporated into electrification decision-making.

2.4 Schools selection criteria

Eskom has been the primary implementation agency responsible for schools electrification for both grid and off-grid electrification. Selection criteria have not been reviewed under this project. The topic has been well reviewed by Borchers & Hofmeyr (1997). Suffice to say here that from a technology perspective, Borchers and Hofmeyr (1997) indicate that schools greater than 3 km from the grid, or from the five-year grid extension plan, are given PV systems rather than grid connections. Eskom staff involved have indicated that it is sometimes difficult to ascertain the grid extension plans, and cases of dual electrification (grid and PV completed by different divisions within Eskom) have been reported.

Critical to school electrification is the support of the provincial Department of Education and the support of the school itself. All schools are required to submit a formal application before electrification can take place.

3. DBSA

Electrification funding is one of the principal activities of the Bank. Since inception of the Bank, total disbursements on electrification have been of the order of 2.9 billion Rands (24% of the total disbursed to all sectors).[3] A recent loan to Eskom of R750 million (the Eskom 1997 Electrification Programme loan) represents a massive injection to the National Electrification programme.

The DBSA offers a number of different loans with fixed or floating interest rates. The latter are sold with some options such as rate capping (with a premium) and rate collaring (where the premium can be zero). Loans can be at concessional rates, or commercial rates. For electrification projects, the concessional rate has applied (between 14 and 15% if fixed rate loan, at the Bankers Acceptance yield rate less 0.45% to 1.45% for a floating rate loan) (DBSA Mandate and Product, no date, DBSA 1997).

Although the Bank does not implement electrification projects directly, it does sometimes play an active role in electrification project assessment for projects that the Bank finances. This applies even within a large programme such as the Eskom electrification programme. For example, they may disallow electrification to certain settlements within a proposal, or suggest alternative settlements to be electrified (apart from those presented in a proposal).

Criteria and principals for electrification programmes are articulated in a number of different documents produced by the DBSA. The Rural Energy operational framework (DBSA 1994) provides a generic approach to energy projects, and lists criteria for appraisal of projects. Davis and Horvei (1995), in a document published by the DBSA, list a range of project selection criteria. The specific focus of the document is on the economic analysis of energy projects. Lastly, of specific reference to grid electrification projects is the appraisal report for the Eskom 1997 loan mentioned above. (DBSA 1997). Annexure 3 of DBSA (1997) lists a set of principles and criteria to guide the implementation and monitoring of electrification of each town identified within the overall DBSA funded portion of the Eskom programme. Important threads relevant to electrification are discussed below.

3.1 Financial and economic criteria

The Rural Energy operational framework (DBSA 1994) lists a number of financial criteria which projects should meet before funding can be approved. These are

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[3] (Stassen 1997). This is a relatively high proportion of funding on a specific intervention and raises the question – should current high rates of electrification be continued in the face of severe budgetary constrains on other important sectors of the developing economy: education, health, water supply, roads?

paraphrased briefly below. *[Comments are indicated in italics and in square brackets].*

- The endusers must be better off *[requires financial analysis from the user perspective].*
- Project must be affordable to all participants such as end-users and intermediaries.
- A cash flow or income analysis is required (at current values). This should include elements such as:
  - return supplier wants to obtain;
  - capital costs (distinguishing between infrastructure and movable assets);
  - economic lifespan of individual assets and the project;
  - operating costs;
  - consumer profiles [*note that this requires more detailed analysis than simply the use of regional average figures; also means that business and community facilities should be looked at specifically*];
  - energy consumption levels (maximum and minimum) [*difficult to predict, commonly regional averages used which do not help to differentiate between settlements];*
  - revenue per unit consumption;
  - cost per unit consumption.

The document goes on to indicate important cost recovery aspects:

- Willingness to pay *[no indication given of how this should be determined].*
- Affordability, both with regard to capital costs and operating costs [*it is not clear how strictly this is applied. Clearly the current electrification programme is strictly speaking not affordable, as revenues often do not even cover operating costs].*

A subsidy policy is stated:

- If subsidisation is considered necessary due to financial shortfalls (and motivated on social or welfare grounds), then:
  - The end-user should be subsidised, not the supply organisation *[Is it possible to target subsidies at one rather than the other? Presumably a subsidy to an end-user will then be paid to the utility in the form of payment for services. There must however be accountability, i.e. that a particular subsidy does actually result in a quantified service being delivered and that profits by the utility are not generated through the subsidy.]*
  - The time frame for subsidisation needs to be set
  - Poorer target groups within the community need to be identified *[Electrification subsidies are usually targeted at entire communities (either in the form of support for community facility electrification, or as a subsidy for household electrification). However, the subsidy is targeted (not necessarily fairly) in that those that do not receive electrification connections do not receive any electrification subsidy].*
  - The operating cost should at least be recovered from end-users. *[This is not always the case for current electrification projects.]*

The DBSA operational framework document also lists a number of 'economic criteria' which should be considered. It will be noted that many of these are related to the need for a holistic, integrated approach.

- These include reference to an economic cost benefit analysis, which should indicate a positive return on investment.
- Energy provision should not be seen as an end in itself, but as an activity in support of economic development.
- Energy provision should be demand driven, based on the needs and priorities of communities.
- Economic linkages should be maximised to ensure optimum development impact.
- An integrated development approach should be adopted in the appraisal, taking into account energy linkages to other services.

The Development Bank uses the same CBA model as that used by Eskom to carry out a financial and economic analysis of electrification projects. Annexure 3 of the DBSA – Eskom programme appraisal (DBSA 1997) requires that an economic cost benefit analysis for each Programme should indicate a positive net present value at a discount rate of 5%. See section 2.3.3.5 and the main report for further discussion of this.

Economic principles and criteria articulated in DBSA (1997) reinforce the need for a holistic, integrated approach:

> Integration/close interaction with other developmental programmes to enhance attainment of the electrification vision of improving quality of life of the rural poor to be strived for;
>
> The programme ... should support sustainable economically rational settlement pattern...
>
> The projects should take into account the electrification opportunities of educational, health and business services within each project.

3.2 Social criteria and community participation

The Bank places considerable emphasis on empowerment of communities involved in energy projects, through access to proper information, and through participation in either negotiating, planning implementing of maintaining energy supply systems (DBSA 1994: 2.3; DBSA 1995b; DBSA 1997: 11).

3.2.1 Information

Proper information includes: analysis of socio-economic activities of the community, community prioritisation of their needs (and distinguishing between individual and domestic needs), identification of potential energy resources, clear information about the implications of different options, and assessing opportunities for community entrepreneurship in energy provision (DBSA 1994: 2.3).

3.2.2 Decision making

Community decision-making and participation in implementation is expanded in DBSA (1994: 2.4).

- Through representative community organisations, joint decision making on affordable provision of rural energy. *[Note, as listed in section 5.8 of the main report, external constraints on resources may limit the options from which the community can choose – the affordability constraint].*
- Communities should be involved in the organisation of local responsibilities for implementation and maintenance
- They should be involved in the identification of needed skills development and training to enable fulfilment of implementation and maintenance responsibilities.

However, in DBSA (1997: 47), it is acknowledged that significant interaction with particular communities is only expected to take place *after* the decision has been taken to target that community for grid electrification:

> Once it has been established that electricity might be available to a particular areas and the demand has been verified, the [Eskom] Customer sales Advisor with the assistance of the [Eskom] Service Centre, interacts with local leaders and a formal or informal committee is usually convened to interact with Eskom.

Thus in terms of the project selection process (perhaps the most important decision), there is tacit acceptance that the community is unlikely to be significantly involved in the decision of whether or not a settlement qualifies for electrification.

3.2.3 Capacity building

Bank documents emphasise the need for capacity development (DBSA 1995a: 1):

> Support to communities to build and improve their own capacity to negotiate, plan, implement and maintain various energy supply systems is crucial to ensure sustainability.

3.2.4 Gender

Specific reference is made to gender in a few of the documents. DBSA 1997 indicates that women should be involved in the electrification committees. From a socio-economic perspective, part of the motivation for electrification is that 'it will release some of the women's and children's time spent in alternative fuel collection, for "more productive employment"' (DBSA 1997: 46). DBSA (1995b: 4) makes specific reference to seeking opportunities for full involvement of both women and men, with attention to affirmative action where women have been severely disadvantaged.

3.3 Technical appraisal of projects

Technical criteria listed in DBSA documents include a requirement 'that infrastructure provided ... will meet demand requirements and be flexible enough to accommodate future needs'. *[This last requirement hides a multitude of complexity. What will the future demand be? It has specific relevance to the design ADMD – see section 3.2.6 of main report.]*

DBSA (1997) (a document relating specifically to the Eskom electrification loan), makes specific reference to the need to seek innovative energy approaches to satisfy needs, minimise financial costs and optimise resource allocation. 'In certain market segments , this will mean *integrating electricity with other energy carriers* in order to meet market needs'.

DBSA (1997) also emphasises the need for the technical approach (particularly with regard to tender documentation and project management) to facilitate the use of local small contractors and the use of local labour. This is expanded to include a requirement that the implementation authority (Eskom) should provide training.

The Eskom Project Appraisal documents (DBSA 1997) and the operational framework (DBSA 1994) do not make specific reference to the standard and quality of electricity supply that should be provided (2.5 A, 20 A and 60 A all receive mention) or to the specific tariffs that should be charged. This reflects the lack of a clear policy regarding the level of service that should be supplied under the current (effectively subsidised) electrification programme.

3.4 Environmental criteria

Environmental aspects of electrification projects are specifically referenced in DBSA documents (DBSA 1994; DBSA 1997). Key aspects include:

- That cost-benefit assessments should include environmental impact, both locally and to society at large.
- That renewable energy sources and energy conservation should be developed to their full potential.

- Understanding that a mix of technologies and energy sources should be developed and tailored to help minimise environmental impact.
- That environmental management is not an end in itself, but a means to satisfy broader economic goals.
- That environmental impact should be minimised in the most cost-effective way.
- That all project participants should have a clear understanding of environmental impacts and take steps as early as possible to mitigate (or enhance positive) impacts.

In regard to grid electrification of projects, the DBSA does not identify major long-term threats, and the key issues are that site rehabilitation take place, and that dust, noise and disruptions be minimised during installation (DBSA 1997).

3.5 Development rationale

The Bank emphasises integrated development, the need to address a broader range of energy supply options than just electrification, and the need for electrification to be targeted at areas where it can be proved to be economically viable (DBSA 1995a). Some of this approach comes through in the above listed criteria (particularly those listed under 'economic'). It is, however, not clear to what extent these approaches actually influence electrification project selection and technology choice.

Reference to the provincial programme appraisal reports attached as annexes to the DBSA Eskom 1997 Appraisal Report (DBSA 1997), indicates that specific attention was placed on a review of the macro-economic situation in the provinces. Specific projects are assessed in relation to economic activity and development potential. Although development corridors in provinces were identified, and areas of greater rather than lesser economic potential noted, many of the settlements targeted for electrification do not fall within in these sites. The principle criteria therefore seem to be socio-economic rather than economic, with the need to redress backlogs a key criteria.

- Settlements 'will probably remain sustainable residential areas' (Mpumalanga).
- '...electrification of the selected settlements/towns will be in support of socio-economic development, inter alia, by stimulating home industries, reducing environmental stress caused by denudation of wood and other fuels, providing lighting for study and entertainment purposes and contributing towards integration of these settlements/towns into more viable entities'. (Mpumalanga).
- Of interest is a recommendation that there should be 'careful targeting of households in all eleven settlements...in order to ensure affordability'. *[This author is not aware that such specific targeting has or can be carried out. It is generally up to the householders themselves to decide whether or not they will take a connection.(Some measure of specific targeting is achieved through the connection tariff.)[4]]*
- In some cases the strongest motivation appears to be redress of an electrification backlog (Free State).
- In the Northern Province, DBSA identified only 44 of the 76 towns/settlements selected by Eskom as satisfying their appraisal criteria for infrastructure support. DBSA suggested that there were additional towns, not identified by Eskom, which should be appraised. *[This is an illustration of the finance agent getting involved directly in project selection.]*

The DBSA Eskom 1997 Appraisal report emphasises:

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[4] The 20 A option has a slightly higher connection fee which means that poorer people may choose themselves to take the 2.5 A supply rather than the 20 A supply.

> The status of other infrastructure in the areas to be electrified must be addressed and Eskom must confirm that no electrification will be done in areas were there is no integrated planning or development taking place.

Attention to integrated energy planning is tempered by an understanding of the complexity of a fully integrated approach. For example:

> The DBSA should be cautious not to confuse clients and beneficiaries by complicating the issue of integrated energy planning and provisions. Although integrated approaches are important, energy should be provided on a demand basis by respecting the wishes of beneficiaries. (DBSA 1995a, pg. 12, paragraph 5.8)

4. National Electricity Regulator

The NER manages the disbursement of grant funding of approximately R300 million (for the 1998 programme) to support electrification by local authorities. These funds were made available by Eskom, as a contribution towards levelling the playing fields between Eskom distributors and local authority distributors (NER 1997a). The DBSA is being used as a banking facility for the disbursement of these funds. See Thom (1998) for a discussion of the principles and criteria used by the NER to guide regional resource allocation.

The principle reference for the local-level criteria discussed below is the document: Allocation of funding for electrification by local authority distributors (NER 1997b).

4.1 Institutional requirements

As a funder to a number of different distributors (there are approximately 400 local authority distributors at present), it is important that the NER ascertains institutional acceptability clearly. The requirements specified in NER 1997a are listed fully below, as these will be of interest to all electrification funding if a significant number of supply agencies continue to operate. (While the number of grid suppliers may reduce in the future, it is possible that the off-grid supply responsibility could be allocated to a diverse range of institutions).

> The funding will be available to licensed distributors who:
>
> (a) meet the NER requirements – e.g. in terms of documentation, approved tariffs, ringfenced accounts;
>
> (b) have the financial, technical and staff capabilities to distribute electricity and to expand the network;
>
> (c) regularly pay their bulk supply account and are up-to-date with payments agreed to with the bulk supplier;
>
> (d) apply credit control effectively;
>
> (e) have consulted their communities regarding their needs for services and energy, their priorities and their ability and willingness to pay for electricity and have obtained their consent to the electrification programmes.

4.2 Financial criteria

The NER specifies limitations on the items for which the grant funding (effectively a subsidy) can be utilised. Costs of public lighting, operating costs and losses, capital cost for higher normal standards cannot be covered by the subsidy. In addition, costs that can be recovered from consumers (reticulation connection, the portion of the capital cost that can be recovered viably through the income generated by these connections) may not be covered by the grant. Lastly, there is a requirement that other sources of subsidy be utilised where possible.

4.3 Prioritisation

The NER (1997b 4.4) gives an indication of the factors to be considered in prioritisation:

- areas requiring a lower contribution will receive a higher priority
- the availability of other essential infrastructural services e.g. water, roads.

The NER also specify that households must be permanently occupied, in 'legally authorised ... designated township development areas'. Reference is made to '(disadvantaged communities)'. This is one of the few instances where any reference by any of the organisations is made to electrification funding only being applicable to disadvantaged areas or poor communities.

4.4 Committee based approach to project prioritisation

The NER issued an invitation to local authorities to submit funding applications. This implies a demand led approach to funding (depending of course on how the local authorities selected their projects for submission).

A technical committee comprising NER staff members and consultants processed these applications to ensure that minimum conditions have been met. These were then prioritised and analysed by the External Electrification Funding Evaluation Committee (EEFEC). This committee has external representation (membership listed in document). The committee forwards recommendations to the NER board.

The above committee approach provides a possible model for electrification funding approval by a possible National Electrification Fund.

5. Independent Development Trust

5.1 Involvement in electrification

The IDT has been significantly involved in clinic electrification, and to a lesser extent provision of energy services to Schools. The organisation has also been directly involved in setting up household electrification programmes and activities in South Africa. This has been at a conceptual level, and has not yet involved major project identification phases. However, it is important to note that the IDT has an extensive database of rural information, and strong linkages to rural communities through their network of project facilitators. The organisation is thus in a reasonably strong position to contribute to electrification planning, particularly for off-grid electrification.

5.2 Clinic electrification criteria

The IDT has supported both grid and off-grid clinic electrification within an integrated clinic upgrading process. Considerable effort is expended to map existing grid lines, and to establish as accurately as possible what the medium term grid plans are. Technology decisions are then based primarily on the distance from the grid, and the size of the clinic and associated staff quarters (indicating the minimum level of service requirements). The guideline grid extension distance criteria used have been modified as the IDT has gained project experience.

Table 5 Criteria to assist health post technology decisions

Technology recommended	*Distance based criteria (Borchers & Hofmeyer 1997)*	*Updated distance criteria (van der Velde 1998)*
Grid	0 to 1 km	0 – 5 km
Diesel genset-plus with LPG for refrigeration	1 – 5 km	5 – 10 km
PV systems	> 5 km	> 10 km

Borchers & Hofmeyer (1997: 32ff) provide a comprehensive review of the primary technology options considered for clinic electrification, and of possible selection criteria. Of key importance is that decisions are made on the basis of a non equal comparison – i.e. off-grid does not provide as complete a service as grid. Areas of difference are listed in table 3 of the main report. Also important is an assessment of service reliability and maintenance requirements. The 1998 criteria listed above reflect a closer approximation to a full life-cycle economically based decision, rather than one based primarily on the cost of simply providing the basic services (lighting, vaccine refrigeration and communication).

5.3 Spatially based planning and longer term planning

Discussions with IDT staff (van der Velde 1998; Viljoen 1998) have indicated two principal areas of concern in electrification planning.

- Firstly, off-grid development is severely hampered by lack of information and certainty regarding grid development plans. This has affected IDT projects, where investments in off-grid technology have been wasted through the subsequent arrival of grid. It has also been identified through efforts undertaken by the IDT to establish a household off-grid programme.
- Secondly, the IDT has placed considerable emphasis on the development of development planning information, primarily in the form of a GIS database. The intention is that infrastructure planning be informed by a clear knowledge of a variety of factors that can be quickly and effectively represented in a spatial manner. This includes the development of first pass cost of supply information for grid electrification.

6. Association of Municipal Electricity Undertakings

Criteria used by members of the Association of Municipal Electricity Undertakings (AMEU) have not been reviewed in detail as part of this project, primarily as a result of project resource constraints. The primary focus of members of the AMEU is in urban or peri-urban areas rather than rural. There is also less likelihood of such utilities exploring off-grid options for electrification.[5] Representatives of the AMEU did however participate in the two project workshops (J Malan and H Beck).

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Criteria to support project identification in the context of integrated grid and off-grid electrification planning

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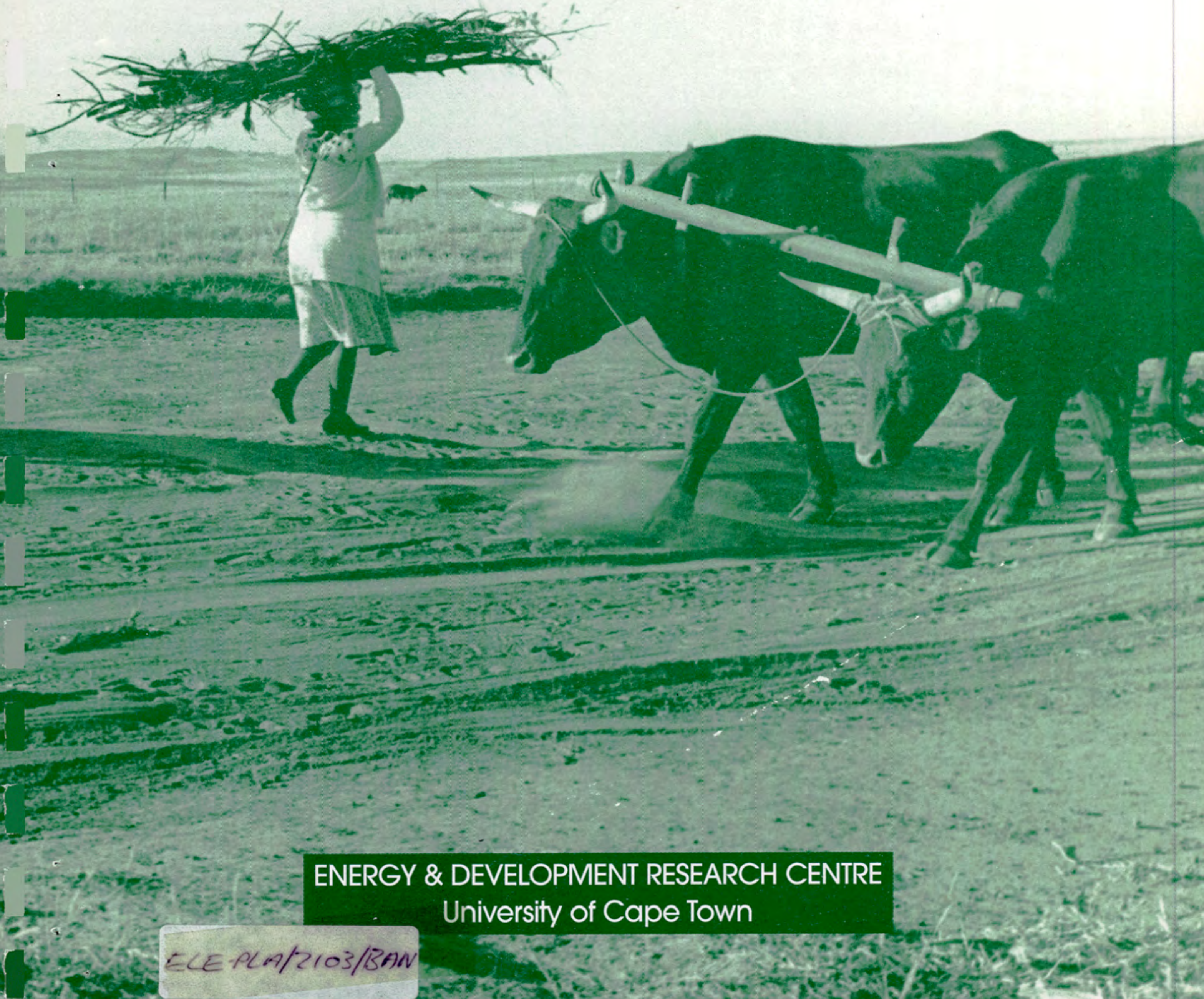

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