CHAPTER 7

DATA BASE

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7.1. Large Power User Database And Manual

7.1.1 Existing Database

A database, similar the one used in the forecast, does not currently exist in Namibia. Data in the country currently exists in various databases, in a variety of formats at the different authorities, institutions and organisations.

(1) Economic Data

The Central Statistics Office (CSO) is the prime source of economic and demographic data. Their data currently is on computer and also available in the form of reports in hard copy format.

(2) Electrical Energy Consumption Data

The country's Electricity Utility, NamPower, has a computer database, which contains inter alia monthly electricity sales in units to all their customers from April 1987 to date. The data prior to April 1987 exists in book form as far back as the seventies. Electricity sales data is therefore available for every customer account number. This data is also available summarised into various categories such as Local Authorities, Mining, Industry (manufacturing), Government and Parastatals, so-called Commercial Farming and Foreign Countries.

Data also exists in various reports such as NamPower's annual reports, where annual data such as energy sales, energy sent out, electricity prices, etc. can be found. Previous forecasts which were done by consultants, also contain electrical energy data in a certain format.

Municipalities have their own data in one or other form. This inter alia consists of electricity sales to all their customers on an individual basis, number of customers, etc.

(3) Other Energy Data

Liquid fuels and coal consumption time series data for Namibia exist for the period 1991 to 1996 in a computer database with the Ministry of Mines and Energy (MME).

(4) Other Data

Namwater has data on water consumption for Namibia by consumer sector per calendar year.

7.1.2 New Database and Manual

The new database has been developed to suit the Sectoral Energy Forecasting Model. It also forms part of this model. Use is made of the standard Excel package on a personal computer. This structure does not require the existence of a separate database.

The database/model contains the necessary data required for forecasting purposes, and the historical data is actually updated in the database/model. There is no necessity for a separate complex database which requires highly skilled human resources for maintaining and updating it. This is a very user friendly database and requires minimum training and no operation manuals. The user, however, must have experience in the use of Excel and personal computers.

Most of the time series data described below are also exist in the form of figures (graphs) in the data base.

Expanding the database is easy. All that has to be done to expand the time series data is to replace the forecast figures with actual figures after every year end. Additional categories or individual customers can be added easily. Further detailing of the existing categories or sectors is also possible if necessary.

Printing from the database/model is easy. As the data is in the form of a very big Excel spreadsheet, it should be printed on A3 size paper, preferably on continuous paper. Selected parts can also be printed. If the historical time series data, as well as the forecast time series data is printed, the spread sheets can be joined.

(1) Economic Data

The database contains first of all historical time series GDP figures by economic sector in real terms from 1980 to 1996 in millions of Namibian dollars. This data was obtained from the CSO in the form of a spreadsheet.

GDP figures of South Africa were also imported into the database, due to the fact that the two economies are still very interrelated. This enables the comparison of for example the growth rates of the two economies.

The model calculates year-on-year growth rates from these figures for the various economic sectors or sub-sectors. The model also calculates the percentage share of the different economic sectors and sub-sectors from these figures.

The database also contains inflation figures in the form of consumer price index figures from 1980 to 1996.

National population figures, obtained from the CSO, were also imported into the database. To this series running from 1980 to 1996 was added the future population figures up to the year 2020. This series was arrived by using certain anchor years and interpolation.

(2) Electrical Energy Consumption Data

The database also contains electricity consumption time series data per annum in GWh by the different categories, sectors, sub-sectors or individual major customers. The time series data is in calendar years for a period of sixteen years, from 1980 to 1996. Monthly data received from NamPower on computer disc, was converted to annual data. Annual electricity sales data prior to 1988 was extracted by hand from NamPower reports in book form.

The large power user data has been arranged in the following format in the database/model, with the customer account numbers next to the individual consumers data:

a) Proclaimed Municipalities and Towns
- Windhoek municipality
- Walvis Bay municipality
- Swakopmund municipality
- Otjiwarongo municipality
- Oshakati town
- Okahandja municipality
- Lüderitz town
- Keetmanshoop municipality
- Mariental municipality
- Rest of proclaimed municipalities and towns
- Total for Local Authorities

b) Mining

- Uranium mining	-	Rössing mine
- Diamond mining	-	Oranjemund mine
	-	Auchas mine
	-	Elizabeth mine
- Copper mining	-	Tsumeb mine
	-	Kombat mine

		-	Otjihase mine
		-	Klein Aub mine (closed)
		-	Oamites mine (closed)
	- Tin mining	-	Uis mine (closed)
	- Gold mining	-	Navachab mine
	- Zinc mining	-	Rosh Pinah mine
	- Other mining	-	As one group
	- Total of Mining		
c)	Industry	-	Existing industries as one group
d)	Water Pumping	-	By major pumping system
		-	Rest as one group

e) Government and Parastatals as one group.

(3) Other Energy Data

Time series data on liquid fuels and coal consumption, in conventional units, together with the conversion factors was obtained from the MME database. From these, the model calculates annual energy consumption in MJ for the period 1991 to 1996.

(4) Other data

National annual water consumption figures for Namibia were obtained from Namwater from 1984/5 to 1996/7 by major category.

Data further back was extracted from the Government of the Republic of Namibia First National Development Plan (NPD1), dated 1995. A sixteen year time series from 1980 to 1996 was also used for water consumption.

Energy price data for the various energy carriers was also imported into the database.

The database contains so called secondary data such as GDP per capita, energy consumption per capita, energy intensity, water consumption per capita, etc. This is data which has been calculated by the model from the primary data, mentioned above in the database.

7.1.3 Database Management System

Updating the database at least once a year is essential. However, should any changes or adjustments be made, or mistakes be discovered, the database should be updated as soon as possible thereafter. The forecast can then also be updated.

The data in the database should be dated and the dates should be changed every time it is updated in order to ensure that the latest version is always be used.

Security of data is very important. Enough backup in the form of discs should be made all the time as computers sometimes give trouble, or hard drives fail. It is also advisable that a hard copy of the spreadsheet be kept.

It is further recommended that access to the database and model be protected through the use of a password.

Protection of the cells is not compulsory, but can be done if required. Excel has a standard procedure to do that.

Improvements to the database should be made on a continuous basis. It is recommended that Standard Industrial Classification (SIC) codes be introduced countrywide in Namibia, i.e. by all suppliers of energy.

Copies of the Fifth Edition, dated January 1993 with latest amendments are available from the Central Statistical Service in Pretoria in South Africa. One copy of this particular edition is submitted with the report. A copy of lists of the major divisions and major groups is attached for purposes of easy reference.

This edition of the SIC of all economic activities, referred to above, is based on the International Standard Industrial Classification (ISIC). The first version of ISIC was published in 1949. Three revised editions have been published since then.

7.2 Small Power User Database And Manual

The small power user model, developed as an Excel workbook, includes an integrated database which contains the summarised statistical information essential for the forecast. These statistical data were derived from several sources and processed before being inserted into the model. In a country like Namibia which has a relatively small electricity supply industry, it is possible to operate a forecasting model like this at present. This chapter serves as a manual for the SPU model and database.

7.2.1 The Existing Database

There is no single existing database that contains all data required to carry out a small power user forecast. The various sets of key data must be collected from different sources.

(1) Population Related Data

Demographic data resides in databases and several reports of the Central Statistics Office. The 1991 Census data entry and validation was carried out on microcomputers using the software package IMPS (Integrated Microcomputer Processing System), developed by the International Statistical Program Centre of the US Bureau of Census. Data analysis was done using IMPS and the SPSS PC statistical software package. The 1993/4 NHIES survey also used IMPS for data entry and validation, but used SAS-

PC for data extraction and statistical analysis. These two data sets are of good quality and were indispensable to the small power user forecast. The 1991 Census was used as the primary source for demographic data in this forecast, with supporting additional information on specific issues being extracted from the NHIES survey reports.

Information about the regional distribution of resources and was obtained from several different Government Departments. This data does not appear to have been systematically captured in any single computerised database by the Government. The data has been summarised in a document called the Regional Resources Manual, produced by the Friedrich Ebert Stiftung. This document has been used as the primary reference on regional resource distribution.

(2) Rural Electrification Data

Rural Electrification planning and progress data exists in part as reports at the Ministry of Mines and Energy. No integrated system for monitoring the progress with respect to connections of different types of customers during the various electrification projects, appears to exist. Figures extracted from the existing reports provided the basis for the rural electrification status used in the forecast. The billing records of Northern Electricity provided additional insight into the types and numbers of electrified entities in the northern regions.

This has made the evaluation of the current status of rural electrification extremely difficult and subject to uncertainty. It is strongly recommended that a progress monitoring and reporting system be put in place prior to the projected large scale electrification of rural areas in future.

(3) Rural Electricity Consumption Data

Rural electricity consumption data exists as billing records in NamPower, Northern Electric, and the Ministry of Regional and Local Government and Housing (MRLG&H). Both NamPower and Northern Electricity keep rural customer consumption data by customer account number. No customer classification is used and no regional information is included in the records as supplied to the JICA team. Rural electrification customer consumption data for the period prior to 1997 was extremely limited and unreliable. It appears that MRLG&H did not have the resources to properly manage and operate an electricity distribution system at that time.

Rural electrification planning to date has not included the evaluation of previous projects or any form of load research to determine local electricity consumption requirements or future demand forecasting. Planning has generally been based on surveys of the villages to be electrified, to determine the numbers of residential, business and government customers in the area.

7.2.2 The New Database and Manual

The small power user forecasting model contains an integrated database of summarised (statistical) information in order to do the forecast. The model at present does not require the existence of a separate database.

(1) Small Power User Forecasting Methodology

The approaches for large and small customer forecasting are quite different. The rural electrification forecasting methodology followed includes the following steps:

- **Customer Classification.** All the small customers in Namibia were grouped together in classes that are expected to have similar consumption and demand characteristics.

- **Class Population Forecast.** The expected numbers of each class of customer for each forecast year were estimated, based on available data. This provided a potential number of customers in each class.

- **Electrification Rate Forecast.** The rate of electrification would usually be obtained from electrification plans and an energy or electrification policy. In this case an electrification rate forecast was developed, based on the assumption of continued equal proportional GDP contribution to the rural electrification effort. This was translated into a hypothetical regional electrification plan for the regional forecasts.

- **Class Consumption Forecast.** The expected consumption and maximum demand for typical customers of each class was estimated. This was based on existing data from Namibia, as well as related experience in South Africa and rural electrification programs in other developing countries.

The elements of these forecasts were combined in the model which provided estimates of the consumption and peak demand requirement for small customers in the future.

(2) The Database and Model Structure

The model was constructed as a number of worksheets in an Excel workbook. The sheets contain models for each region as well as supporting data sheets and associated charts (see Figure 7.1).

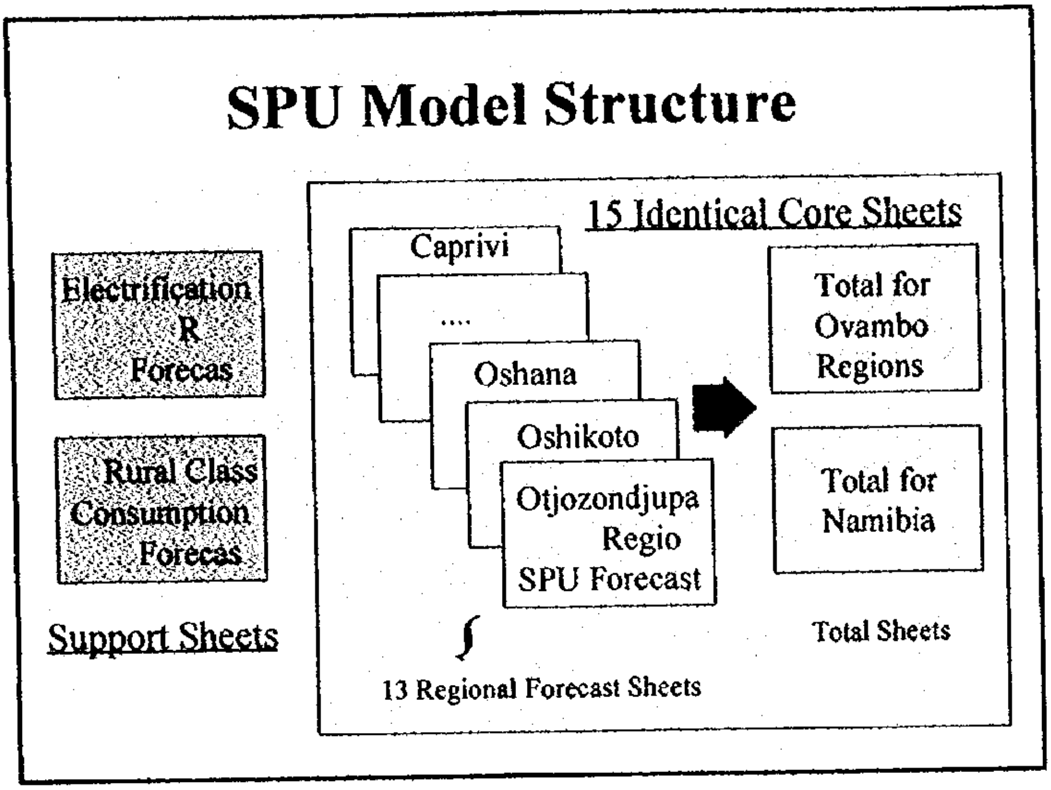

Figure 7.1 - SPU Model Structure

The core sheets are a set of 13 forecast sheets, one for each region. These are titled by the first letters of each region name. These sheets are ***Cap, Ero, Har, Kar, Kho, Kun, Oha, Oka, Oma, Omu, Osha, Oshi***, and ***Otj***.

There are two sheets which sum the regional forecasts, one for the whole country (***Total***) and another for the four regions that make up the previous Ovamboland (***Ovambo***). The ***Ovambo*** total has been specifically requested by MME.

There are several supporting sheets which contain data and analysis to provide inputs required by the core sheets. These include ***Local*** and ***Refs***. There is a sheet containing the average annual consumption expected for each type of rural customer for each forecast year, called ***Cons***.

There is a set of sheets establishing electrification rates for each of the GDP growth assumptions for the three forecasts, ***2%, 3,5%, 5%, and Rates.***

Lastly, there are a number of charts illustrating various aspects of the forecast.

(3) The Core and Sum Sheets

The layouts of the 13 core sheets and the sum sheets are identical (see Figure 7.2) and described briefly as follows:

a) Population Growth Forecast

The first section deals with the population and expected population growth, for urban and rural areas (as defined and used in the 1991 Census). The population growth rate for each region is currently set to equal that of the nation, set in the ***Total*** sheet. Note that the growth rate for each region can be set individually if so desired. Similarly, the urbanisation rate is currently set in the ***Total*** sheet but could be set separately for each region. Several scenarios for both Growth and Urbanisation rates have been built into the ***Total*** sheet, and can be selected from the Tools/Scenarios menu. There are four population growth scenarios currently installed in the model. These are the three rates from the Provisional Population Projections document and a fourth based on the moderate rate with a reduction due to the impact of AIDS as expected in the UNDP report on Namibia for 1997. There are also four urbanisation scenarios installed. A rate of 3% which is approximately equal to the population growth rate and included for demonstration purposes only. Rates of 5% and 5,4% which are reasonable and a high rate of 8% which is a possibility mentioned in the NDP1 document, but considered unlikely.

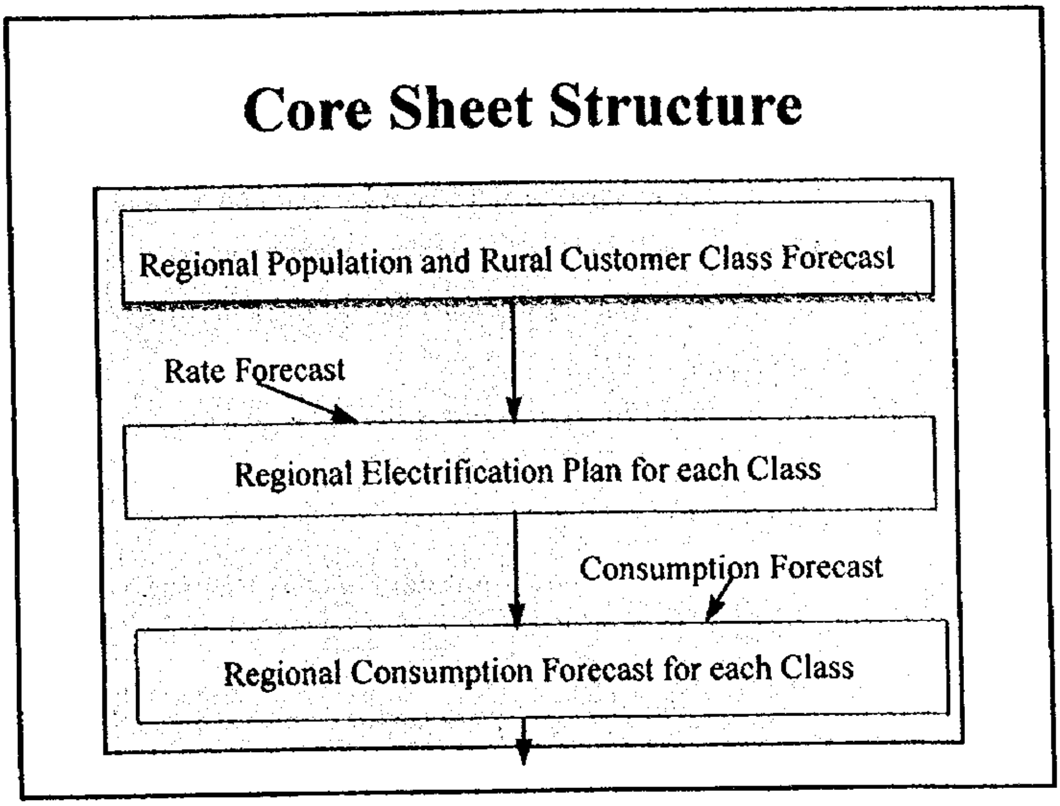

Figure 7.2 - The Core Sheet Structure

b) Rural Households Forecast

This is followed by a section that derives the numbers of urban and rural households from the population figures. The numbers of people per household vary from region to region and have been taken from the 1991 Census data. These have been assumed to remain constant over the forecast horizon. Rural households have been further split into Village Households and Dispersed Households, due to their different electricity requirements and likely electrification rates. This division was based on locality sizes and demographic attributes documented in the NHIES survey of 1994. The supporting data for the division are contained in the sheets ***Local*** and ***Refs***. Note that in some cases the sums of Village and Dispersed Households do not exactly equal the numbers of rural households from the 1991 Census reports.

c) Other Rural Class Population Forecasts

There are population forecasts for each of the other rural customer classes on a regional basis. These were based on all available resource documents and discussions with local experts. In many cases the class forecast was approximately the same as the national population growth forecast.

d) Rural Electrification Plan

The rural electrification plan - number of connections per customer type per year - was inserted for each region. This is a hypothetical rural electrification plan which was developed for the forecast. It was derived from assumptions about regional electrification priorities as indicated by MME and in various documents.

It must be noted that this plan is only illustrative of an actual plan. It implements rural electrification at the overall rate derived in the Rate sheet, based on a constant proportion of GDP contributed to electrification - but the regional allocation of connections is arbitrary. This means that the overall demand of the electrification forecast will reflect the total connection rate correctly, but the regional distribution of the demand may be incorrect. The plan figures must be updated with actual plan figures once they become available.

e) Total Rural Electrified Customer Base

This section keeps track of the cumulative totals of electrified customers according to the electrification plan and the initial base of electrified customers.

f) Proportions of Customers Electrified

This is followed by a section listing the percentages of each customer type that have been electrified to date. It compares the cumulative totals for the electrification plan to the cumulative totals for the customer growth forecasts. This acts as a check to ensure that the electrification plan is reasonable and produces the desired results.

g) Rural Electricity Consumption

The annual consumption per customer class per region is calculated from the total customer base and expected annual consumption in the Cons sheet. The consumption for all rural customer classes is then summed to provide a total for all rural customers in each region.

h) Rural Maximum Demand

An estimate for the maximum demand in each region imposed by the rural load is done using the assumed load factor method. A diversified load factor of 40% was applied.

(4) The Electrification Rate Forecast

The rate of rural electrification in Namibia will be limited primarily by financing constraints. The JICA team developed a rate forecast assuming that the proportion of GDP spent on rural electrification over the past six years will be maintained, and that the capital cost per connection would not change. These assumptions were modelled for the three GDP growth rates used in the energy sales forecasts, in the sheets *2%, 3,5%, 5%*. The outcomes for these rate forecasts are summarised in the sheet ***Rates***. This sheet also contains a number of other rates modelled, including that proposed in the draft Namibian Energy Policy document and a continuation of past post-independence electrification rates.

(5) The Supporting Sheets

The Refs sheet contains a list of the main reference documents from which key figures were extracted. In several cases different figures were in different documents, and those considered most accurate were used in the model. This sheet also contains tables derived from the model and used in the rural forecast document. A set of tables comparing key population statistics from the 1991 Census, model forecast, and NHIES survey of 1993/4 is also in this sheet. The Local sheet contains the tables and calculations dividing rural households into village households and dispersed households. This was complex due to discrepancies in definitions used in data from different sources.

(6) The Data used in the Model

This section describes the data sources used and data processing required for data sets used in the model. This process will not need to be repeated for historical data, but may be necessary when updating the model in the future.

a) The Population Forecast Data

The 1991 Census was used as the source for population figures on a regional basis for rural households, as well as the numbers of urban and rural households. The institutional population was considered to be urban. Note that the population of the Walvis Bay enclave was not included in the 1991 Census, but this is not serious as the enclave is almost entirely urban - and does not affect the rural population figures.

Several population growth scenarios were built into the model. The first three were the annual growth rates in the Provisional Population Projections (PPP) document published by the CSO in 1994. The impact of AIDS, as determined by the UNDP, was imposed on the Moderate

PPP rate to create a fourth scenario. The population growth rate in each region is set equal to the national rate (set in the *Total* sheet, Row 11), but this could easily be changed to give each region it's own growth rate if desired.

The national urbanisation rate is also set in the *Total* sheet (Row 12). There are several urbanisation scenarios built into the model, which automatically caters for inter-regional migration. Urbanisation scenarios include 3% (the population growth rate), 5% (the base case), 5.4 - 5.8% as expected by Windhoek Municipality, and 8% which is mentioned in the NDP1 document as a possibility. As with the population growth rate, the user can insert any desired urbanisation rate or give regions different rates.

The model calculates the number of people per urban and rural household in each region from the 1991 Census figures for regional population and household figures. These figures are then used to determine the numbers of rural households in the future. The division of rural households into villages and dispersed communities is also based on 1991 Census data and the 1993/4 NHIES survey.

b) The Electrification Rate Forecast Data

A forecast of this nature is usually preceded by a rural electrification plan. In this case, a hypothetical plan had to be developed in order to carry out the forecast. This plan was based on all available information from MME, previous electrification projects, and the Draft Energy Policy document. The plan assumed a concerted long-term effort to electrify the rural areas in the northern regions, as this was the priority according to MME. Businesses in these regions were aggressively targeted in order to stimulate development in these regions. This plan is described in the small power user forecast document. Note that the plan currently implemented in the model is arbitrary, and probably allocates regional rural demand incorrectly, although the total rural demand will reflect the electrification rate assumptions correctly. Actual planned regional connection figures must be inserted into the regional sheets when these become available.

7.2.3 Database Management

The data sets used in the model can be updated as required by the user. The following sections identify the areas in the model that can be easily updated by a user.

(1) Demographic Data

There should be no need to alter the population or population growth figures in the near future. If this model is still in use after the next Census, the new population and household figures can be inserted in the 13 regional sheets. If the AIDS epidemic continues unabated, it may be necessary to revise the population growth rate scenario in the ***Total*** sheet, or simply to select the built-in AIDS scenario. Note that changes to the population figures to not affect the electrification demand forecast, but will affect the proportions of customers electrified.

(2) Current Electrification Status Figures

The present figures in the model were derived from the limited information available to the JICA team. As with the demographic data, these figures will not affect the rural demand forecast, but will assist with the evaluation of proposed plans and progress monitoring. ***It is strongly recommended that MME monitor the progress of future electrification projects in a methodical manner and update these figures in the model annually.*** This will permit the evaluation and adaptation of electrification plans to cater for changing circumstances as they develop.

(3) Rural Electrification Plans

This is the most important section of the forecast model. The hypothetical plan implemented in the forecast is almost certainly different to electrification plans as they will be developed. The present regional distribution of rural demand is based on the hypothetical plan, which could allocate the rural demand to regions incorrectly. ***It is vital to update these figures for each customer type in each region, as new plans are accepted for implementation.*** Revised figures will result in a revised demand forecast being calculated immediately, with all charts and associated tables also being updated.

(4) Rural Customer Consumption Data

The annual consumption expected for each type of rural customer is listed in the Cons sheet. These data are based on existing billing records from NamPower and Northern Electricity and in most cases no growth has been assumed.

It is strongly recommended that all institutions supplying electricity to rural customers, such as MRLG&H, NamPower, and Northern Electricity, implement the following procedures as soon as possible:

- All rural customers must be classified according to the types used in the forecasting model. Alternatively the SIC classification system, recommended for large customer classification, can be used.

- The total number of customers in each class and their total class consumption must be reported to MME on a monthly basis and recorded for future updating of the model.

MME should track these data which will indicate both the progress of rural electrification projects as well as consumption growth rates for the different customer classes. The totals can then be used to update the model annually.

(5) Database Security

Data security is easily overlooked, and often only becomes noticed once it is too late to prevent loss or damage. The Excel spreadsheet represents several man-months of work and must be safeguarded as such. There are two aspects to the security of the small power user forecasting model.

The first is the security of the Excel file itself. It is important to maintain at least two backup copies of the file, in different locations to the computer on which the model resides. These backup copies must be updated every time the model is updated.

The second relates to the access or alteration of possibly sensitive information contained within the spreadsheet itself, by unauthorised people. For this reason the model should be protected by a password. A password protection facility is available in Excel.

7.3 Maximum Demand Forecast Database And Manual

7.3.1 The Contribution to Load Factor MD Model

The maximum demand model is a simple spreadsheet which implements a Contribution to Load Factor forecast on the total class sales figures produced by the two forecast models (see Figure 7.3). No database is required for this model. The model consists of three identical spreadsheets, one for each forecast, see Figure 5.3. The workbook includes several charts illustrating system maximum demands and forecast load factors.

The changes in the NamPower system demand profile were derived from data obtained from NamPower, who maintain their own database for the system demand profile. Again, no additional database is necessary.

7.3.2 Recommendations for Future MD Forecasting

The coincident class load factors used in the forecast are based on the experience of the authors in Eskom, where a considerable amount of load research expertise has been developed. These are considered sufficiently accurate at this stage due to the similarities between Eskom and NamPower with respect to customer types as well as tariff structures and levels. It is strongly recommended that demand profiles for each key customer and samples of the smaller customers be obtained to verify the coincident class load factors. Key information on customer load factors, diversity,

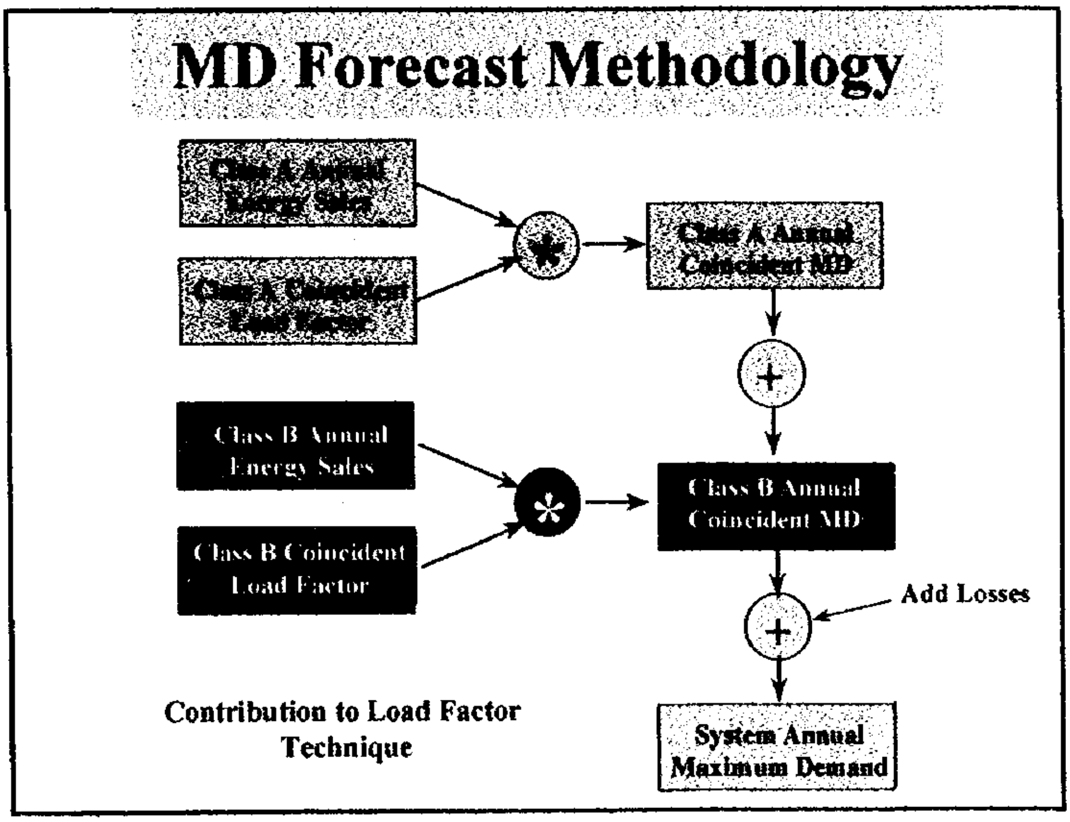

Figure 7.3 - Maximum Demand Forecasting Methodology

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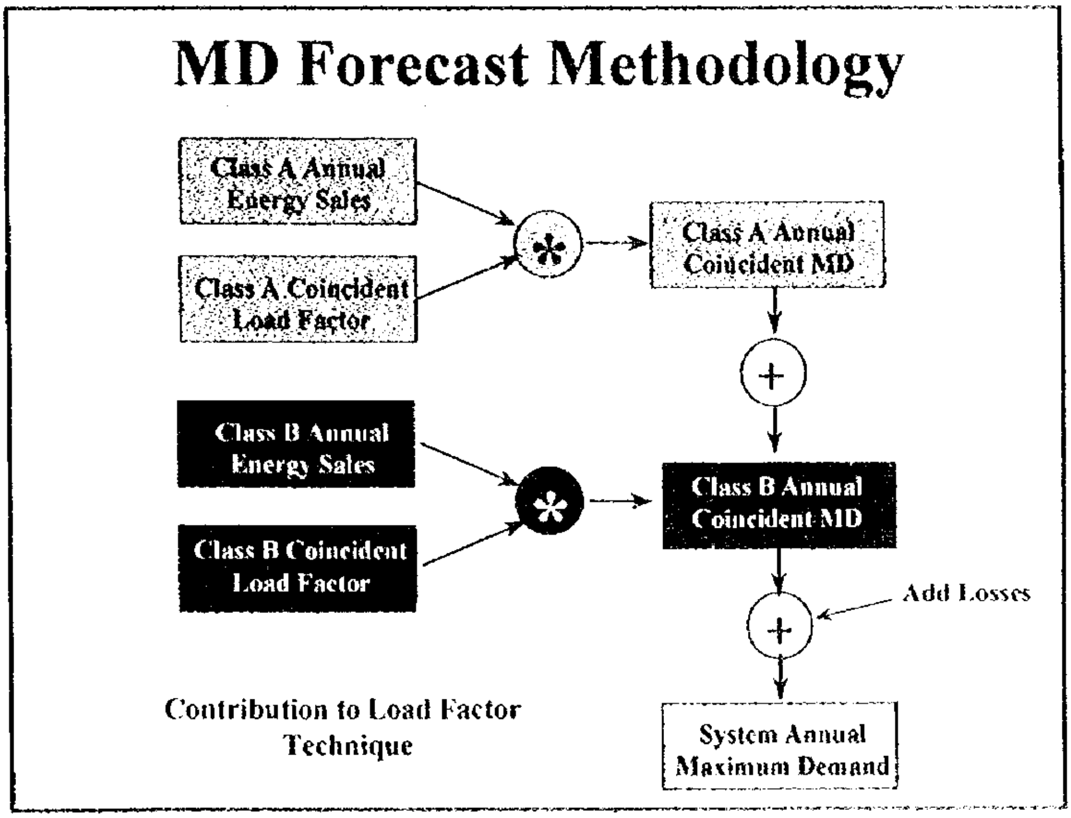

Figure 7.3 - Maximum Demand Forecasting Methodology

seasonal demand variations, and even temperature sensitivity of demand will help optimise future expansions. This load research data will prove invaluable to Namibian utilities in forecasting, 'least cost' system planning, cost reflective tariff design, and customised sales agreements. This will become even more important if Namibia develops a self-sufficient electricity supply industry, as proposed in the draft energy policy.

Note: SIC Code Summary is attached to Annex-1.

CHAPTER 8

RURAL ELECTRIFICATION

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8.1. Present Situation of Rural Electrification

Approximately 30% of Namibia's households had access to electricity in 1997. It is estimated that more than 75% of the urban households use electricity, compared to only 8 to 9% of the households in rural areas. Electricity distribution is decentralized, with 46 municipalities and local authorities being responsible for supply to end-users in urban and peri-urban areas. NamPower supplies directly to large mining and industrial consumers and to about 1,500 commercial farmers. Supply in rural areas is mainly the responsibility of the Ministry of Regional and Local Government and Housing (MRLGH), although operation and management of supply in the northern part of Namibia has been contracted out to a private company (Northern Electricity). NamPower also has an involvement in rural areas, being responsible for the main rural transmission and distribution system and direct supply to certain end-users.

8.2. Present Progress of Rural Electrification

The draft White Paper on the Energy Policy of Namibia 1998 describes the following:

"It is estimated that rural household access to electricity has increased from 5% in 1991 to 9% in 1997. Although the electricity grid will continue to be extended to rural areas, it is not likely that the majority of rural households will have access to grid electricity. The reasons for this lie with the high cost of electrifying dispersed rural villages coupled with the low consumption of electricity by rural households. Despite this, electricity does provide benefits for rural households by improving quality of life. Electricity also provides important services to rural people where it is supplied to community facilities such as clinics, churches and schools, as well as rural businesses. Government will continue to electrify rural areas where are economically viable and target community facilities, small business and households. Renewable electricity will be made available in off-grid areas for community facilities, including for the provision of water supply, as well as for small businesses and households."

Access to reliable and affordable energy services is necessary for economic growth and social development in rural areas, and as a means of redressing past imbalances. Electricity provision plays a major role in this context. Ongoing and planned rural electrification projects aim at connecting approximately 12,000 additional rural households to the grid by the year 2000. In order to provide a tangible contribution towards improving the socio-economic situation in rural areas, it is Government's intention that at least **25%** of rural households shall be connected to the national grid by **2010**. Attention will be also given to the needs of commercial farmers and farm-workers in rural areas.

Reaching the 25% target will require annual investments of N$30 million or more. The Ministry's Energy Directorate will be responsible for overseeing the rural electrification programme.

Renewable energy systems, in conjunction with enhanced supply of petroleum fuels, will substitute grid electrification in areas where it is not viable to extend the national grid. Renewable energy might also provide an interim, first-step solution in areas where access to the grid is not envisaged in the short term to medium term.

8.3. Rural Electrification Programme by MME

The rural electrification programme started by MME in former Ovambo in 1991, financed by a NORAD grant, extended to Okavango in 1992, financed by the Namibian government and followed by the eastern part of the country and then to the southern rural areas, being financed jointly by the Namibian government and Norway. Some villages in the west are also being electrified.

The programme of rural electrification is moving clockwise around the country. Site survey of the master plan on rural electrification for the northern part of the country (conceptual design only) financed by MME was finished by Reselec and Stewart Scott in March 1998. This is for the second round of a national rural electrification programme.

Priority targets for the rural electrification projects are socio-economic centres such as schools, clinics, hospitals, churches, mission stations, development projects and other public institutions. This is an important point to pay attention. The rural electrification so far might be called a town development. Social institutions in comparatively large locality centres and only the nearby households have been electrified. The cost of electrifying more dispersed rural villages is becoming higher, coupled with the low consumption of electricity by rural households.

The following centres will be connected to the national grid during the period 1996-2000:

Aroab, Koës, Klein Vaalgras, Kommnarib, Blou-Wes, Koichas, Gabis, Warmbad, Tsumis, Schlip, Rietoog, Duineveld, Fransfontein, Kamanjab, Orumana, Anker, Erwee, Omatjete, Tubusis, Spitzkoppe, Otjimbingwe, Lisikili, Kalimbeza, Isize, Bukalo, Ikumwe, Ngoma ,Gunkwe, Makolonga, Masokotwani, Malundu, Kanono, Chichimani, Muketela ,Linyandi, Mafuta, Imukusi, Ausincluding around these centres.

Actual conditions of diesel generators prior to the electrification programme
According to SWAWEK 1994 report, diesel generators were in use in the main grid for electricity industries only at Paratus and 45MW isolated diesel generators were operated by DoW to supply to government institutions and socio-economic centres. There are 3MW isolated diesel generators for electricity industries at Katima Mulilo.

For 30 settlements in the Owambo area, engineering consultants recorded the presence of 100 diesel generators of various sizes (Torbich 1995). Approximately half of these were located at public buildings , and the rest were at shops, private homes and mission stations. The DoW had the responsibility of operating and maintaining generators at public buildings, and often kept back-up sets at each site.

Locality	Capacity	Use	Cosumption
Okahao	500kVA	hospital, admin, schools	20,000 l/mtn
Tsandi	580kVA	2 schools, hospital	20,000 l/mth
Onesi	433kVA	school, clinic	15,000 l/mth
Outapi	125kVA	school	10,000 l/mth
Outapi	300kVA	clinic	20,000 l/mth
Anamulenge	not reported	clinic, 3 schools	30,000 l/mth
Oshikuku	400kVA	mission hospital, 3 school	30,000 l/mth
Omungwelume	216kVA	school	7,000 l/mth
Ongha	50kVA	school	5,000 l/mth
Engela	178kVA	mission, hospital	6,000 l/mth
Oshigambo	30kVA	school	1,200 l/mth
Enhana	360kVA	school	11,000 l/mth
Okongo	10kVA	hospital	600 l/mth

Source: Review of Owambo Rural Electrification Programme, EDRC 1995

The EDRC's report on Owambo review (1995) shows the cost of operating and maintaining diesel generators is 63Nc/kWh(1995 term) including fuel cost. On the other hand, energy charge in MRLGH's electricity tariff is 29Nc/kWh(1997 term) for O & M cost of diesel generators. Government institutions in the electrified areas are achieving a considerable saving.

8.4. Rural Electrification Plan by NamPower

8.4.1. Introduction

The NamPower's Electricity Master Plan for Namibia which includes the rural electrification plan sets a framework for development of the Namibian generation capacity, transmission and distribution systems primarily for the year 1996 to 2006.

This master plan is designed for co-ordination with the rural electrification project schedule of MME. This project schedule seeks to supply power to numerous small rural settlements. Many of these settlements fall into the areas covered by the new commercial farming projects in the section 8.4.3. Those falling outside these areas are dealt with in the section 8.4.2. as communal area projects.

The section 8.4.2 deals with projects designed to reach communal areas of the country, which includes projects identified by MME.

The section 8.4.3 deals with the new rural commercial farming projects designed to reach new areas of the country previously not covered by farmer schemes. Many of these projects require investment in system extensions at 132kV or 66kV level, and a number of these projects includes rural communal settlements.

As for the distribution system around 800km of 66kV overhead line terminating in at least 12 new 66/33kV substations is envisaged to bring power to the commercial and communal farming areas of the country.

From these and existing substations 26,000km of 22 and 33kV overhead lines must be built to reach about 3,500 commercial farms. In most of these farming areas are rural settlements and small centres which are to be electrified along with the farms.

To complete the planned distribution systems will take at least 30 years at an estimated total capital cost of N$900 million (1996 value) according to NamPower.

8.4.2. Electrification Projects for Communal Area

NamPower mentions the followings in its Rural Electrification Plan:
These projects must be regarded as important because of their social context.
The electricity requirements in these areas are initially very different from those of commercial farming areas, because few if any dwellings are equipped to use electricity and few people can actually afford an electricity supply at economical rates.* Ways and means have to be found to make ultra low-cost low capacity supplies available to the general population of these areas.

* Reselec and Stewart Scott are planning single wire earth return (SWER) 19.1 kV power lines in the northern part, which could halve the line cost. They have to make clear issues of 1) inductive disturbance on telecommunication line and 2) unbalanced load before practical utility.

It is proposed by NamPower that an in depth study be undertaken to determine what kind of electricity supply would be affordable to the population of these areas and what their electricity requirements are in the short and medium term. Technical solutions can then be investigated to meet these criteria, and sponsors can be solicited to supply projects that will bring power to rural people's dwellings in an economically sensible and practically usable fashion.

A summary of projects identified by MME can be found in Table 8.1, showing approximate costs for the high voltage extensions. No money has been allowed for low voltage (400V/230V) connections in any of the projects, so these will have to be budgeted for by MME.

Table 8.1 COMMUNAL PROJECTS (As of 1996)

No.	Area	66kV Line km	66kV Line cost	66kV S/S cost	33/22/11kV km	33/22/11kV cost	Supply point cost	Total HT Cost	Commercial Scheme:
1	Aroab / Koes	110	4400000	1300000	110	2420000	500000	8620000	Scheme 24
2	Tsumis, Schlip, Duineveld	0	0	0	100	2200000	300000	2500000	Scheme 17
3	Rietoog	0	0	0	25	550000	50000	600000	Scheme 13
4	Franstontein / Kamanjab	90	3600000	500000	0	50000	600000	4750000	Being done 1996
5	Orumana	0	0	0	25	550000	50000	600000	
6	Erwee & Anker	0	0	0	40	880000	50000	930000	Scheme 11
7	Omatjette & Tubussis	0	0	200000	60	1320000	200000	1720000	
8	Caprivi 1-Ngoma	0	0	1300000	103	2266000	400000	3966000	
9	Caprivi 2 - Linyandi	0	0	0	85	1870000	400000	2270000	
10	Gabis	0	0	0	0	0	0	0	completed in 1995
11	Wambad	0	0	0	40	880000	150000	1030000	Scheme 28
12	Koichas, Komnarib etc	0	0	0	65	1430000	450000	1880000	
13	Otjimbingwe	0	0	0	50	1100000	150000	1250000	Scheme 22
14	Okongo	120	4800000	1300000	0	0	0	6100000	
15	Aus	0	0	0	50	1100000	50000	2870000	Scheme 27
16	Spitzkoppe	0	0	0	50	1100000	50000	1150000	from Scheme 22
	Total	320	12800000	7100000	763	16836000	3500000	40236000	

8.4.3. New Major Commercial Farming Schemes

NamPower's master plan proposes the development of 17 new major rural electrification schemes in commercial farming areas. These schemes together with existing schemes will make electricity accessible to nearly all commercial farming areas in Namibia. The proposed new schemes cover roughly 63% of commercial farming areas of Namibia, while together with existing schemes 90% of commercial farming area is covered.

The schemes include major addition to existing commercial farming schemes. These projects do not require 66kV or higher system extensions, but in some cases a 33kV or 22kV feeder in an existing substation is required.

A summary of the commercial farming schemes is provided in Table 8.2.

Table 8.2 Commercial Farmer Scheme Summary (As of 1996)

No.	Area	Tot km	cons	km/cons	retic cost	Add cost	System Cost	Tot cost	cost/cust
1	Tschudi	1,080	200	5.40	262,60,000	1,800,000	2,110,000	30,170,000	150850
2	Aranos Nosth	870	159	5.47	211,27,500	1,440,000	0	22,567,500	141934
3	Platveld	1,010	183	5.52	245,07,500	1,800,000	4,350,000	30,657,500	167527
4	Omatako	1,360	239	5.69	329,07,500	2,340,000	0	35,247,500	147479
5	Seeis	690	118	5.85	166,55,000	1,080,000	1,200,000	18,935,000	160466
6	Hochfeld	1,380	225	6.13	331,72,500	2,340,000	0	35,512,500	157833
7	Berg Aukas	2,335	376	6.21	560,70,000	4,140,000	200,000	60,410,000	160665
8	Kalkfeld	1,770	281	6.31	424,52,500	3,060,000	3,150,000	48,662,000	173176
9	Buitepos	325	51	6.37	77,87,500	540,000	200,000	8,527,500	167206
10	Omaheko South	1,045	162	6.45	250,15,000	1,800,000	200,000	27,015,000	166759
11	Kamanjab	1,310	199	6.58	313,07,500	2,340,000	1,200,000	34,847,500	175113
12	Omaheko North	1,160	171	6.78	276,57,500	1,980,000	0	29,637,500	173319
13	Klein Aub	1,460	214	6.82	347,95,000	2,520,000	1,000,000	38,315,000	179042
14	Aranos East x 1	410	60	6.83	97,70,000	720,000	200,000	10,690,000	178167
15	Ombika	500	73	6.85	119,12,500	900,000	200,000	13,012,500	178253
16	Omaere South	655	95	6.89	155,97,500	1,080,000	0	06,677,500	175553
17	Blumfelde	1,470	213	6.90	350,02,500	2,520,000	400,000	37,922,500	178040
18	Gochas	1,115	156	7.15	264,80,000	1,980,000	5,150,000	33,610,000	215449
19	Omaere North	400	55	7.25	94,87,500	720,000	0	10,207,500	185591
20	Swakoppoort	342	47	7.28	81,11,500	540,000	200,000	8,851,500	188330
21	Matchless	720	97	7.42	170,52,500	1,260,000	1,200,000	19,512,500	201160
22	Karibib	725	97	7.47	171,62,500	1,260,000	4,850,000	23,272,500	239923
23	Mariental East	560	67	8.36	131,57,500	900,000	0	14,057,500	209813
24	Aroab	2,080	238	8.84	487,35,000	3,600,000	5,950,000	58,285,000	244895
25	Maltahöhe	1,720	185	9.30	401,52,500	3,060,000	6,750,000	49,962,500	270068
26	Mariental West	775	82	9.45	180,75,000	1,260,000	0	19,335,000	235793
27	Konkiep	1,800	190	9.47	419,75,000	3,240,000	1,200,000	46,415,000	244289
28	Karasburg	1,825	189	9.66	425,12,500	3,240,000	7,950,000	53,702,500	284140
29	Keetmanshoop	625	64	9.77	145,50,000	1,080,000	200,000	15,830,000	247344
	Total	31,517	4,486	7.03	749,449,000	54,540,000		851,849,000	189891

8.5. Scheme Co-ordination between MME and NamPower

This subsection provides an investigation into the co-ordination between MME's rural electrification programme and NamPower's rural electrification plan.

In construction of rural electrification facilities it is routine that NamPower constructs 33kV class high tension (HT) feeders from a secondary substation to bulk supply points while low tension (LT) distribution lines and reticulations are constructed by MME. Costs of construction and maintenance of the HT feeders will be additionally included in NamPower's tariff and be substantially borne by rural consumers.

The rural electrification programme and plan themselves are well co-ordinated between MME and NamPower and there is no discrepancy between the programme (identified centres by MME) and the plan (communal projects in Table 8.1). Electricity supply from NamPower grid to the electrification projects covering 38 villages and rural centres, which has been executed or will be executed by MME from 1996 to 2000, are identically shown in Table 8.1. However it does not include cost for LT distribution lines and reticulations, which is the responsibility of MME.

The commercial farming scheme in Table 8.2 planned by NamPower is being executed from 1996, spending more than 30 years. Many of these projects require additional 132kV or 66kV level transmission lines and many of these projects include rural communal settlements. MME will be able to save the cost of rural electrification for the communal area from the year 2000, if making plan that such facilities as 132kV or 66kV transmission lines will be utilised for the rural electrification as well as the commercial firming.

8.6. Off Grid Electrification and Development of Renewable Energies

8.6.1. MME's Activity on Renewable Energy

(1) General

At this stage, all public programmes dealing with renewable energy are coordinated by the Primary Energy Resource Development Unit (PERD) of Ministry of Mines and Energy. Namibia does not give priority at the moment to the utilisation of renewable energy as far as large scale electricity generation is concerned, however an important position of renewable energy in future is fully recognised.

In terms of expertise, GTZ of Germany has made one long term renewable energy expert available to MME, and NVE an advisor on all energy sectors.

(2) Study on Renewable Energies

The government of Namibia is proceeding resource measurement campaigns as far as wind and solar is concerned, with the co-operation of Gesellschaft fur Technische Zusammenarbeit (GTZ) of Germany. Proposal for an implementation strategy have been completed on the viability of the erection of two wind parks of which the capacity is 20MW in Walvis Bay and 10MW in Luderitz respectively. MME has commended further a feasibility study on wind generation for these areas, and will be completed by November 1998.

For the study on erection of large solar thermal plant, measurement of solar radiation has been completed at Noordoewer which was selected as potential site of the plant.

(3) Revolving Fund for Use in Disseminating Solar Power Generation

a) Outline of the Revolving Fund

Namibia has established the Revolving Fund for the dissemination of solar power generation. The official title of this project is the Peri-Urban And Rural Energy Supply Revolving Fund, but it is commonly referred to as simply the Revolving Fund. This enables non-electrified households in rural areas to obtain loans for purchasing solar home systems (SHS), and the combined contribution of Government and NORAD amounted to N$1 million was made to the Revolving Fund in 1996/97 and 1997/98 respectively. The implementation phase started in December 1997 and to date about 80 SHS of mixed sizes, but mostly 100 Wp have been installed during this phase. The total number of SHS installed through the revolving fund scheme to date is thus approximately 180.

This project is implemented by the Namibia Development Corporation (NDC) under the auspices of MME, and a steering committee consisting of members from both these organizations has been established to manage implementation.

b) Project Objectives and Course of Implementation

The project aims to raise living conditions in non-electrified regions where grid distribution cannot be expected to reach in the near or far future, through promoting electrification based on solar home systems (SHS) that meet demand on the household level. Also, this project entails the development of solar technicians in regions who are capable of carrying out SHS installation works and maintenance, etc. Doing this will supplement the income of such technicians and help perpetuate the effectiveness of the project.

The pilot phase of the project was successively conducted between April 1996 and March 1997, and the second phase, which was commenced from the end of 1997, is currently in effect. As a result of the pilot phase, in which the emphasis was placed on the installation and dissemination of standard sets with 50 W output, approximately 100 sets were installed in households in the six regions of Omusati, Ohangwena, Oshana, Oshikoto, Caprivi and Omaheke. Up to now 100 solar technicians, of whom about 10 are female, have been trained in training courses financed by GTZ.

In the second phase, as a result of incorporating the opinions of regional citizens that became clear in the pilot phase, households are able to select from three types of SHS and the project targets all 13 regions.

c) Contents of SHS

Three types of SHS are currently on offer through the revolving fund scheme during the second phase - the 5 Wp type (System A), 50 Wp type (System B) and 100 W (2 x 50 Wp) type (System C). System B was introduced in the pilot phase, while the other two types have been adopted from the second phase onwards.

These systems prescribe power for lighting and reception of TV and radio for social communication as the minimum required level of electrification, and they are designed with the aim of purely supplying power for these uses. Naturally, use of these systems does not cover heavy power consuming electrical appliances such as electric heaters for cooking and heating, air conditioners and refrigerators, etc. For this reason, the Government of Namibia has been striving to diffuse cooking heaters and stoves that use liquefied petroleum gas (LPG) from the second phase, and is aiming to achieve its original target of raising living conditions in regions through combining this with SHS.

Table 8.3 shows in outline form composite specifications of SHS.

Table 8.3 Specification of Solar Home System

Type	Component to be included	Remarks
System A	1 x portable 5 Watt solar panel 1 x portable 5 Watt lantern 1 x portable transistor radio	Transport to be included
System B	1 x 50 Watt fixed solar panel 1 x 12 Volt battery (90 - 100 Ampere-hours) 1 x regulator 1 x power gauge 4 x 9 Watt lights 1 x 12 Volt plug point to connect TV or radio	Transport, Installation and insurance to be included
System C	2 x 50 Watt fixed solar panel 2 x 12 Volt batteries (90 - 100 Ampere-hours each) 1 x regulator 1 x power gauge 8 x 9 Watt lights 2 x 12 Volt plug point to connect TV and radio	Transport, Installation and insurance to be included

d) Loan System

All Namibians living in areas not covered by the NamPower grid are basically able to apply for a loan, however, the repayment capacity of applicants is investigated by the NDC after applications have been received. The criteria for investigation are as indicated in Table 8.4. In the pilot phase, out of 360 applications, only 96 succeeded in paying their deposits of 20%. NDC believes that, because this investigation system exists, there are currently no applicants from the pilot phase who have become incapable of repaying their loans.

Applicants who pass the NDC investigation conclude a purchase contract with the NDC and receive the installation and handing over of equipment by technicians who are appointed by the NDC. A general example of the purchase cost is indicated in Table 8.15, however, because differences exist in transportation cost depending on the distance from the equipment maker in Windhoek, the purchase cost varies by around +/- 3% between districts.

Table 8.4 Selection Criteria

a)	The applicant must be economic active
b)	The age of applicant must not exceed 65 at the end of the loan term. An age of less than 58 years is preferred.
c)	Priority is given to an applicant living outside the national electric grid.
d)	The applicant must receive a minimum income of: • N$3,600 per annum to qualify for the Solar Lantern System • N$16,000 per annum to qualify for the 50 Watt SHS • N$35,000 per annum to qualify for the 100 Watt SHS
e)	The applicant must have a clean credit record of no civil judgments.
f)	The applicant must not have an existing loan at the NDC.

Table 8.5 Prices for Solar Home Systems (N$)

	Deposit	Insurance (See Note 1)	Legal Fee (See Note 2)	Monthly Payment	Cash Payment
System A	231.00	—	2.00	17.45 (x 60 months)	1,157.00
System B	1,279.50	170.00	7.00	96.66 (x 60 months)	6,578.50
System C	2,248.80	230.00	12.00	169.00 (x 60 months)	11,436.00

Note: 1. Insurance for 5 years
2. Legal fees payable per system
3. Prices of cash payment includes insurance fee and legal fees

Source: NDC

e) Overseas Assistance for the Project

Concerning assistance for the project from other countries, NORAD has contributed NOK 1 million (about N$670,000) in 1997/1998 and NOK 1 million in 1998/1999, and REFAD (Renewable Energy for African Development) contributed N$150,000 in 1997/1998, but may not be used for extending loans. It is only to be used as collateral and is only to be accessed in case of large-scale default by end-users.

f) Analysis of the Project

Since the project has only recently been commenced, it still faces a number of problems, the most important of which are described in the following paragraphs.

a. The first problem concerns the fact that the project only deals with small capacity systems that do not allow general domestic electrical appliances to be used. For comparatively wealthy households that desire solar systems with larger capacity, the revolving fund cannot be utilized. In view of this, consideration should be given to widening the choice of systems that are on offer.

b. Next, although efforts are being made to spread the installation of SHS in combination with LPG, the project (Revolving Fund) only applies to SHS. LPG use is desirable from the viewpoint of mitigating forest destruction, however, in order to diffuse both LPG and SHS, it is necessary to reconsider methods of implementation that do not rely solely on the project.

Despite problems like those indicated above, the Revolving Fund is being put to actual use and is judged to be a worthwhile concern. Since the start of the Revolving Fund Project, the project management committee has afforded constant changes to the project mechanism in order to streamline and optimise it, this should be continued.

Note) Although NDC brochure reads SHS cannot power stoves, refrigerators or similar equipment and NDC application does not seem to accept more than the 100Wp SHS, there are comments from a MME official that there is no restriction on the number of system that a customer can purchase through the schem.

g) Development of the Revolving Fund

Currently, use of the Revolving Fund is limited to three types of system, but the range of system choice should be widened further in the future. The three available systems are so small in capacity that they cannot be applied to cooking appliances, and it is not possible for comparatively wealthy households to use the Revolving Fund to purchase order made systems of larger capacity. If it is made possible for more people to utilise the Revolving Fund through reviewing the loan screening criteria, and so on, it is anticipated that this will contribute to the further diffusion of solar power generation.

8.6.2. Potentiality of Renewable Energies

(1) Solar Energy

Generation capacity by solar energy depends on the available land area and the quantity of solar radiation. Namibia has a great potential of success in solar generation due to its uniqueness in geographic features represented by the Kalahari and Namib deserts.

The average energy density of the solar radiation impinging on Namibian soil is higher than that experienced in any other countries. The radiation intensity is relatively large in Africa as well as Australia. It is reported that the country has an average of around 3,300 hours of sunshine per year, and the annual average solar radiation over the whole country on a horizontal surface is estimated to be about 2,200 kWh/m^2.

However, because solar power generation facilities are used to collect energy of low density, the cost per unit output is high and continuous output cannot be obtained. In view of these disadvantages, solar power generation facilities cannot become major facilities within the power network, but their role must be limited to auxiliary power generation.

Table 8.6 shows some model study results describing the estimated capacity of large generation plants assuming that they are installed in the large deserts of the world. Conditions for the calculations are shown below.

a. Solar battery arrays are installed at about the half area of the desert.

b. The reference solar radiation is assumed to be the same as the horizontal global solar radiation at the area nearest to the field among those listed in the world radiation database published by the Japan Weather Association.

c. The conversion efficiency of the solar battery modules is 14%.

d. The overall system output factor is 0.7 considering the aging of batteries and BOS (Balance of System) efficiency.

Table 8.6 Available Solar Energy in Large Deserts

Continent	Area	Annual average solar radiation	Annual average radiation intensity	Available power	Annual generating energy
Unit	($10^4 km^2$)	($MJm^{-2}d^{-1}$)	(kWm^{-2})	(TW)	($10^4 TWh$)
North America					
Great Basin	49	20.32	0.235	34	4.97
Chihuahua	45	19.68	0.228	32	4.41
Sonoran	31	17.21	0.199	22	2.63
Mojave	7	21.16	0.245	5	0.75
Sub-total				93	12.76
South America					
Patagonia	67	12.81	0.148	47	4.27
Atacama	14	22.08	0.255	10	1.57
Sub-total				57	5.84
Australia					
Great Victoria	65	21.57	0.250	46	6.98
Great Sunday	40	23.11	0.267	28	4.59
Simpson	15	21.57	0.250	11	1.61
Sub-total				85	13.18
Asia					
Arabia	233	22.24	0.257	163	25.69
Gobi	130	16.53	0.191	91	10.66
Karakum	35	16.34	0.189	25	2.84
Kyzyl-kya	30	16.34	0.189	21	2.44
Taklamakan	27	16.19	0.187	19	2.18
Kavir	26	18.33	0.212	18	2.34
Syrian	26	18.10	0.209	18	2.31
Thar	20	21.44	0.248	14	2.13
Lut	5	21.09	0.244	4	0.53
Sub-total				373	51.12
Africa					
Sahara	860	23.52	0.289	602	106.69
Kalahari	26	22.54	0.261	18	2.88
Namib	14	22.54	0.261	10	1.60
Sub-total				630	111.17
Total				1,238	194.07

(2) **Wind Energy**

In Namibia, general weather data is mostly available. But few detailed long-term records for winds, of which average wind speed vary over the country, are available. It seems that few data for evaluating the potential of large-scale wind generation properly, is available in Namibia as well.

According to available data, the highest wind speed is found along the coast. Wind speeds of inland commercial farm areas are too low for power generation, however, it is applicable to multi-rotor type wind turbine, which used to be utilised for water pumping from a well. Toward the north of the country, wind speeds are lower and long-time calm happens sometime so that no wind turbine for generation or pumping can be operated.

Namibia is generally calm without damages from a so-called cyclone.

8.6.3. Possibilities of Development of Renewable Energies

(1) Characteristics of Renewable Energy

Renewable energy types (mainly solar and wind power) are discussed here to describe their characteristics and possible methods for application.

a) Incentives and challenges

Technologies for renewable energies have been matured enough for large-scale applications. Energy policies, irrespective of developing countries or advanced countries, are now based on:

a. Cost-performance

b. Diversification of energy sources, and stable supply (energy security), and

c. Environmental impacts.

In light of these aspects, renewable energies are characterized as follows:

For item a) above, photovoltaic generation needs cost (per kW) more than 10 times as high as that for conventional generation systems. Significantly large facility cost for constructing solar generation systems contributes to this financial disadvantage.

For item b) above, it should be recognized that primary energies (solar and wind power) depend on the topographical and/or meteorological conditions in each region (country).

For item c) above, renewable energies are environment-friendly, and consequently socially acceptable, which acts as a strong incentive to their introduction. Adverse factors that are impedimental to their introduction are that environment cost cannot be accommodated in the tight financial structure.

b) Energy supply systems to rural areas

Photovoltaic and wind power generation systems, which are of a dispersed system, have the following advantages.

a. Region specific supply systems can be configured.

b. Demand-oriented systems can be constructed; construction time is shorter; and enables flexible planning in construction and expansion.

c. It is possible to construct where no commercial power systems exist; doesn't need construction of transmission facilities; and doesn't need fuels other than solar or wind power.

These advantages of a dispersed system of renewable energy are appreciated by many electrification projects for such rural areas as being inaccessible to conventional power systems.

(2) Concept on Use of Renewable Energies

Concept on use of renewable energies is written in the draft White Paper. Namely, with the major problems of the Namibian energy sector being its high dependency on energy imports, the large disparities in access to energy services between urban and rural areas, and the alarming deterioration of the woodland resources, the Government has embarked upon a Programme on the Promotion of the Use of Renewable Energy Sources. Mindful of these problems, Government committed itself to promoting the use of renewable sources of energy wherever this is technically feasible and economically viable by signing the Harare Declaration on Solar Energy and Sustainable Development at the World Solar Summit in September 1996.

The following is institutional challenges required by the draft White Paper which has to be considered when studying the possibility of using renewable energy sources:

a. The establishment of an adequate institutional and planning framework, which provides for the balanced provision of all forms of energy, including renewable energy, according to economic and social merit;

b. Development of human resources and public awareness, as a condition for sufficient sustainable human capacity in the sector;

c. Set-up of suitable financing systems for renewable energy applications, in order to increase their affordability and encourage economic choices which are based on life-cycle costs;

d. Improved co-ordination among government ministries engaged in energy provision;

e. Improved access to energy, specifically for rural energy users, to attain a better quality of life and socio-economic development in rural areas; and

f. Achieving increased self-sufficiency, security of supply and sustainability in the electricity sector, through the use of renewable energy for electricity generation, and through rational use of energy measures.

(3) Possibility of Introduction of Photovoltaic Power Generation

Options of decentralised solar PV systems for rural electrification could be cheaper than extending the grid over long distances, allowing for improved efficiency especially in remote areas. On the other hand, the price of PV systems is still expensive although it has been coming down.

Here assuming a model case or in every probable individual case regarding dispersed communities isolated the grid, comparison of rough cost between a case of PV systems installation and a case of grid extension shall be carried out in order to estimate the scope where PV systems adoption is economically advantageous. Needless to say, PV systems are now technically feasible.

a) A Model of Dispersed Communities for PV Systems Planning

It is deemed that one dispersed community would be a minimum unit for implementation of rural electrification as the national policy.

The distributioin of Namibia's population can be classified into two groups. As indicated in section 6.3.5 Regional Class Population Forecast, in several regions (Ohangwena, Okavango, Omusati and Oshana) there are about five several dispersed communities for each village. The remaining regions (with the exception of Oshikoto) have over 50 dispersed communities per village. Similarly the average size of a dispersed community in the north is 155 persons, while it is 22 persons in the other regions. Since the average household size is 5.4 persons in the rural areas, the household number of a modelled dispersed community in the north is 29, while it is four households in the other regions.

b) Capacity of PV Systems

A disperse community with smaller number of electrifying households and less installed capacity has the wider scope favoured by PV systems in rural electrification of a remote area from the national grid. In other words, the objective of PV systems could be dispersed communities composed of low-income households with the low consumption of electricity.

Although PV systems could be cheaper than the grid electrification, the investment costs are still at a high level. The generating cost is extremely high despite the high solar radiation in Namibia. Accordingly the Namibian government would bear the high financial burdens. MME's opinion on PV sytems in the rural households electrification is as follows: "The government cannot afford the high capacity. It should be minimum requirements. The capacity should be on non-thermal basis and 100 Wp per household. PV systems should provide electricity for lighting, radio and television. For cooking purposes, LPG will be the most practical solution." This MME's policy can be supported as a measure to reduce government's expenditure and to attempt the spread of rural electrification to the tips of dispersed communities.

It is estimated that the cost of a 100 Wp PV system is N$8,500 (unit price 85,000 N$/kW), taking into consideration international market price as well as the cost of SHS in Namibia. Maximum possible usable energy of this system is approximately five kWh per month, fluctuating depending on a area, the season and the weather. This means the capacity factor is only 6.9%. Assuming economic life of 30 years, interest rate of 3%, and operating and maintenance cost of 1%, life-cycle cost is 8.6 N$/kWh, which is 25 times as high as 34 Nc/kWh of the current MRLGH prepayment electricity tariff. This is fairly high cost.

The nationwide average capital cost for grid electrification of a modelled rural settlement composed of 100 households is approximately 8,600 N$/household, excluding the capital cost of the incidental socio-economic centres added to each household. (Refer to annex 2 section 14) This net capital cost for grid electrification is nearly the same as the capital cost of a PV system. This could make a implementation guide for PV systems clear. And it is not likely to be of use that PV systems might provide an interim, first-step solution in areas where access to the grid is not envisaged in the short to medium term.

c) Grid Extension to Give the Same Cost as PV Systems

To supply electricity to a dispersed community, 66kV line is not required because of its small power demand, and it is only required to extend the nearest 33kV/22kV distribution line. 33kV distribution lines are considered in this study because there is no big difference in the construction costs between 33kV and 22kV lines.

ACSR 25mm^2 (Gopher) is schemed for conductors of the distribution lines in order to keep the minimum strength. Distribution transformers are to be 25kVA (33/0.4kV) which is the smallest in the standard frame. Costs of LV distribution lines are negligible small in this case. No consideration is required to a current rating and a voltage drop. The followings are to be used as the costs of distribution facilities in this study:

33kV Distribution Lines : N$22,000 /km
25kVA Transformer : N$15,000/bank

In the case of the modelled dispersed community in the northern and the central/southern Namibia, more advantageous scope for the PV systems is more than 10.5km far from the existing or schemed distribution lines in the northern and more than 0.9km in the central/southern as shown in the following table 8.7:

Table 8.7 Generalised Guide to Potential Area for PV Systems

Area of model community, Number of households	PV systems installation costs	Scope favourable to PV systems from grid
Northern, 29 households	N$246,000	over 10.5km
Central/Southern, 4 households	N$34,000	over 0.9km

In reality, there are various sizes of settlements in the unelectrified dispersed communities and unelectrified small localities are scattered in the electrified areas. Therefore, it is very difficult to demarcate the areas favourable to PV systems or to grid extension. It is advisable that individual estimation be made to every case because the installation cost per rural household is almost even all over the country. The following table 8.8 shows distribution line length that can be extended at the same cost as PV systems installation for a group of households connected to one distribution feeder. Namely, the scope far from this line length is favourable to PV systems, in other words, a potential area for PV systems.

Table 8.8 Rural Household Number and Potential Area for PV Systems

Household number	1	2	3	4	5	6	7	8
Line length, km	0	0.1	0.5	0.9	1.3	1.6	2.0	2.4
Household number	9	10	11	12	13	14	15	16
Line length, km	2.8	3.2	3.6	4.0	4.3	4.7	5.1	5.5
Household number	17	18	19	20	21	22	23	24
Line length, km	5.9	6.3	6.7	7.0	7.4	7.8	8.2	8.6
Household number	25	26	27	28	29	30	35	40
Line length, km	9.0	9.4	9.8.	10.2	10.5	10.9	13.5	14.8
Household number	45	50	55	60	70	80	90	100
Line length, km	16.7	18.6	20.6	22.5	26.4	30.2	34.1	38.0

d) Examinations

In the programme of rural electrification, community facilities such as schools, clinics, government services and businesses were given priority, followed by village households. Dispersed households were electrified only once all other connections had been completed in a region. Government will continue to electrify rural areas which are economically viable and target community facilities, small businesses and households (the drat energy policy). Therefore the smallest dispersed communities with less than 200 residents and almost none of community facilities is likely to be electrified lastly. It is presumes that the rural electrification will start in dispersed communities around the year 2020 and step into the smallest settlements of dispersed communities around the year 2040 at a rate of electrification envisaged by the draft energy policy.

It is deemed, from the said articles, that **there is the possibility of PV systems installation in the whole dispersed communities** with less than 500 residents. Especially there is the very high possibility in the dispersed communities with less than 200 residents (smallest dispersed communities). In Namibia exist more than 9,500 smallest dispersed communities, detailed information on which is not available. (1991 Population and Housing Census)

NamPower has got a long-term distribution extension plan for rural electrification. Figure 8.1 shows its distribution system coverage in the future, **the outside of which** is deemed to be totally favourable for PV systems installation, that is, **potential areas for PV systems** exclusively. There are only the smallest dispersed communities in these areas except for the villages of Tsumkwe and Gam in Otjozondjupa region. They are unlikely to get grid electricity in the near future due to their extreme remoteness. Figure 8.2 shows the distribution of human population and the area for distribution and PV systems.

The distribution system coverage areas in Figure 8.1 is complicated to be a mixture of grid-connected or to-be-connected rural village communities and non-electrified dispersed communities, and is deemed to be **possible areas for scattered PV systems.** It is difficult and not practical to now identify possible areas for scattered PV systems in the grid-electrified areas. It is advisable that individual estimation be made to every case according to Table 8.8 at need.

A 100Wp PV system restricted to minimum requirements enables electrification up to an isolated house in the smallest communities, with relating cheaper cost than grid extension, although it has a limitation on the use of electricity. Early implementation of PV systems will be possible regardless of the past priorities. PV systems might provide an interim, first-step solution in areas where access to the grid is not envisaged in the short to medium term. The Government will have wider options on the rural electrification policy. Funds will be made available for rural electrification will be allocated between grid and off-grid energy supply options, and on the basis of their social and economic merits according to the draft energy policy. It is estimated that the household number of the smallest dispersed communities which have the high possibility of PV systems installation will be 30% of rural households i.e. approximately 92,000 in the year 2020. That implies the potential number of PV systems is approximately 92,000 together on the outside and the inside of the distribution system coverage areas.

c) Issues concerning Introduction of PV Systems

After the installation of PV system completed, organization for check, maintenance and repair becomes more important. PV system has a battery for the storage of solar energy generated during day time, and provide electricity for lighting and for operating electrical equipment such as television set and radios. Then PV system including a battery which functions with chemical reaction, requires check and maintenance by expert who has special knowledge for the battery, though PV cell itself is maintenance-free device except removing dust. For repair of electrical circuits, technicians who have knowledge of electrical work, should cope with the situation too.

For this point of view, it is quite effective that SHS technicians who have finished NDC's training course, cope with the installation and the maintenance of PV system in the rural area. This is because SHS technicians will also serve after-sales services as local retailers for Windohoek-based companies supplying solar systems, as well as installation ordered by NDC, and thus total service system including installation, checking, maintenance and repair by SHS technicians can be realized. If this way as SHS is spreading more, doing this will help perpetuate of PV system in the rural area.

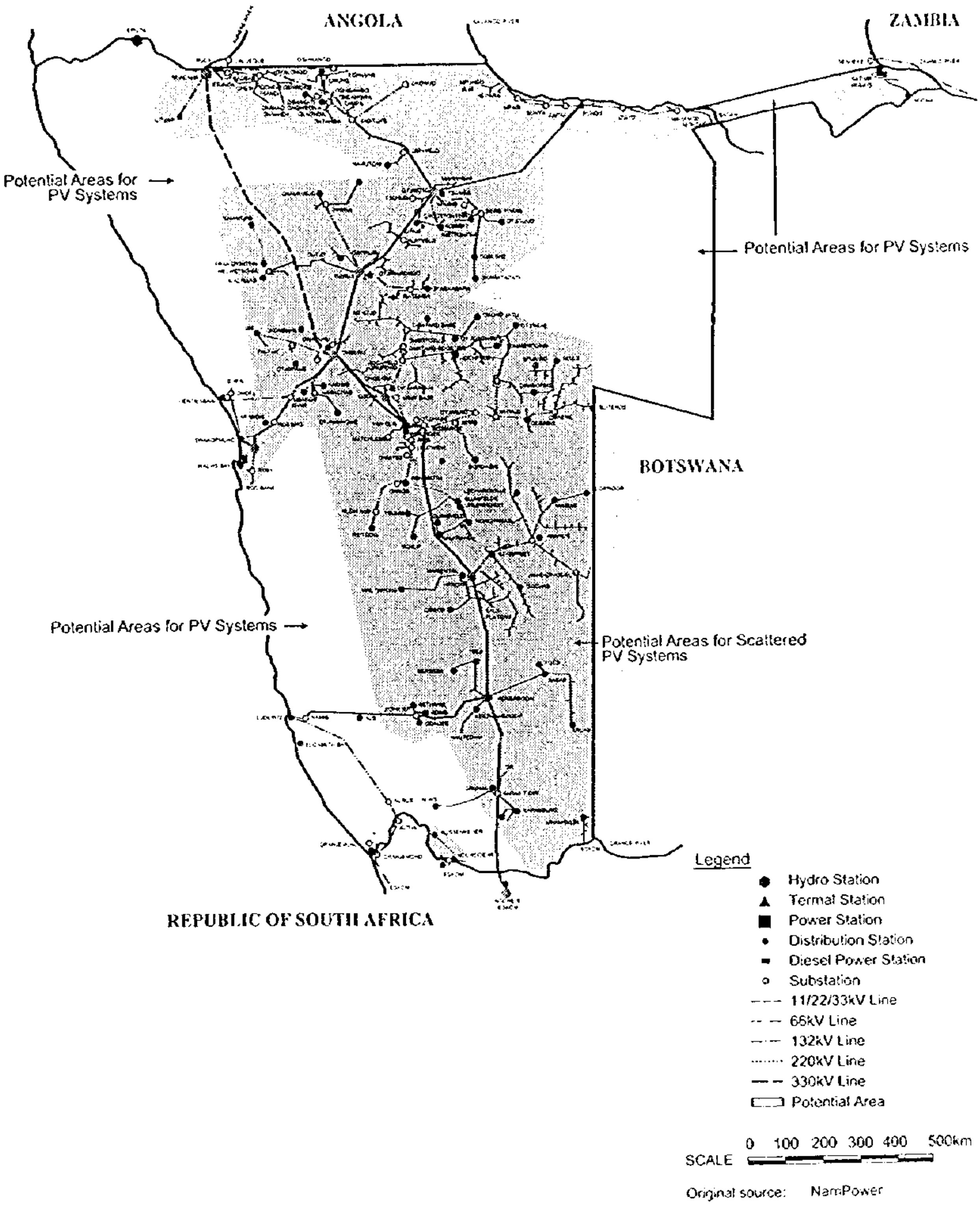
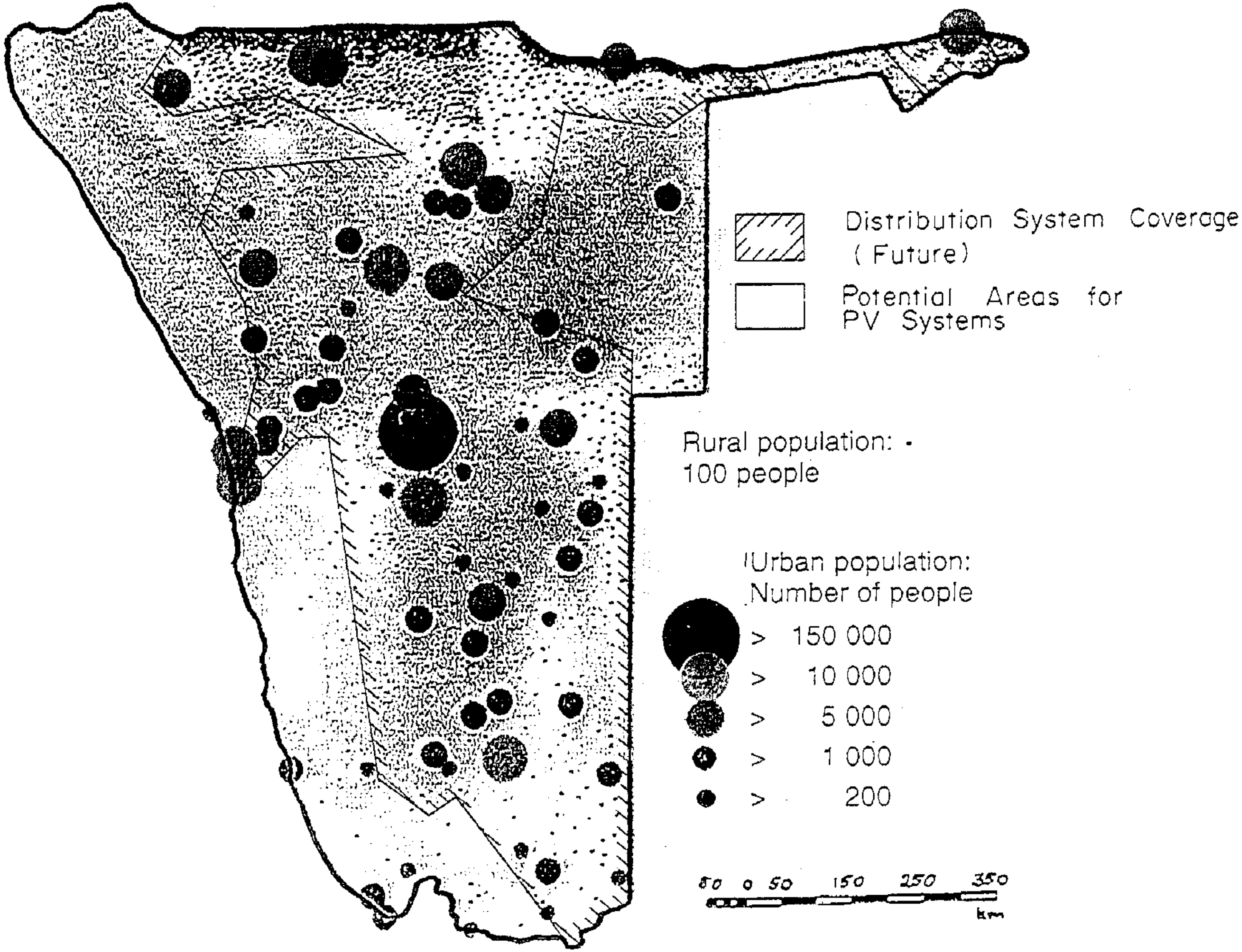


Figure 8.1 - Distribution System Coverage-Future

Figure 8.2 The distribution of Namibia's human population



SOURCE: NAMIBIA ENVIRONMENT

(4) Possibility of Development of Wind Energy

a) General

The history of wind power to generate electrical power goes back about 15 years. Wind turbines were commercialised in 1980s and their installed capacity worldwide exceeds 8,500MW in 1995 (Surveyed by Dr. W. Horrighs, Balcke-Dürr AG, Germany). Wind turbines are being developed over a range of outputs from 1kW to multi-MW units. Machines currently used for commercial generation of electricity vary from 300kW to 1,500kW. A large scale wind farm requires a number of machines to be grouped together for economy and ease of operation. The machines are usually spaced 5 to 10 rotor diameters apart to reduce interaction effects. A wind farm of about 20 machines usually extends over some $3km^2$ to $4km^2$ of land.

So called oil crises greatly caused interest in wind power during 1970s and in the early 1980s the US federal and state governments introduced substantial tax allowances for investments in wind power as well as obliging electricity utilities to buy power from such installations at favourable prices. Germany has introduced electricity legislation which compels utilities to purchase wind-generated electricity at a premium rate from producers. The British government has encouraged the commercial exploitation of wind energy in the UK though the non-fossil-fuel obligation and related schemes.

The rate of installation has declined following the withdrawal of tax concessions. Instead, recent government regulations on the reduction of CO_2 emissions were the decisive factor leading to greater use of wind power in western Europe. Countries such as Germany, Spain and the UK are increasingly promoting the use of renewable energy sources such as wind.

b) Technology

Wind is a complex resourece. It is intermittent, intensively fluctuating and strongly influenced by geology and topgraphy. There is a cubic relationship between instantaneous wind speed and available power. Wind mill output P is

$$P = 2\pi R^2 V^3 \rho (1-\alpha)^2$$

where ρ: air density V: wind speed R: rotor radius α: retardation

A typical advanced wind turbine has a capacity of 500kW, a hub height of 40m, and a rotor diameter of 41m. No power is generated in wind speed less than 4.5m/s (cut-in wind speed). The rated output is reached at a wind speed of 12.7m/s and remains roughly constant up to a wind speed of 28.8m/s (cut-out wind speed). Over the cut-out wind speed the turbine is closed down for a safety. The turbine can survive against a wind speed of 60m/s (Refer to Figure 8.3).

The variability in wind speed over short periods is often perceived as a major disadvantage of the resource. This can normally be accommodated in a well-functioning electricity grid. The maximum technically acceptable contribution from wind power to a grid is generally reckoned to be in the range 10-15% of its operating capacity but this has not yet proved a limit on wind power installations.

The output of wind power installations depends entirely on the wind conditions from moment to moment. It is therefore regarded as non-dispatchable capacity and reserve power must be available to deal with any drop in the wind power contribution.

c) Wind survey in Namibia

A project has been established to assess the potential for utilizing wind energy to generate electricity at two coastal sites, Walvis Bay and Lüderitz. Wind measurement devices were installed at Walvis Bay and Lüderitz on 31 October 1995 and 12 December 1995 respectively. The installation of 30m masts and associated equipment at Walvis Bay and Lüderitz will be implemented in the near future. Figure 8.3 shows a typical expected performance curve of a wind generator.

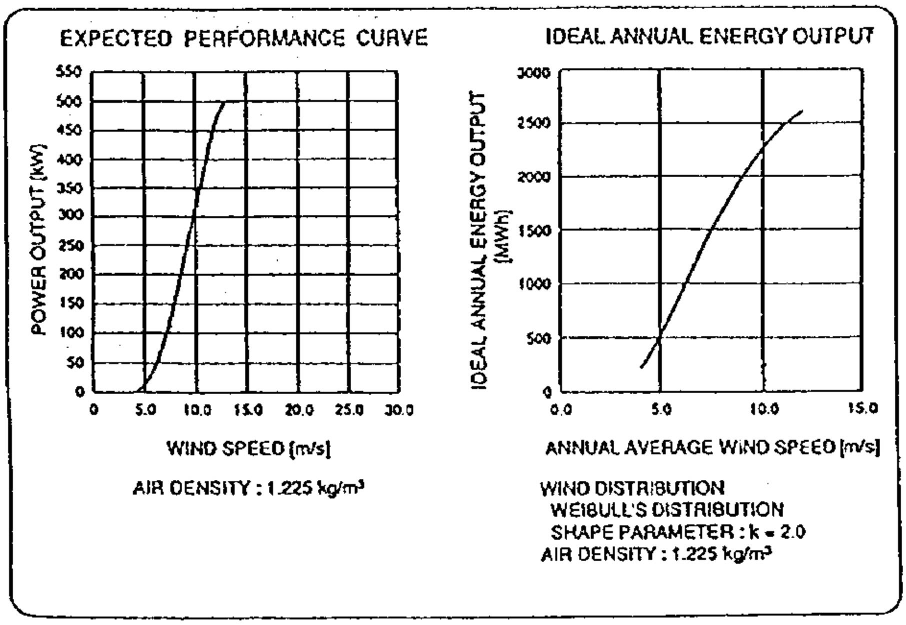


Fig. 8.3 Expected Performance Curve and Ideal Annual Energy Output

Source: A major wind turbine manufacturer

The following is wind data from Final Report on Wind Energy Evaluation Programme for Wlvis Bay and Lüderitz by Manx wind Energy Services. Only one year data is available at moment between November 1995 and December 1996. Annual MWh per MW is estimation by JICA study team.

Table 8.8 Summary of Wind Data for Walvis Bay and Lüderitz

	Walvis Bay		Lüderitz	
Month 1995/96	Mean Wind Speed m/s	Maximum gust m/s	Mean Wind Speed m/s	Maximum gust m/s
November	6.53	19.50		
December	5.08	18.40	5.95	25.30
January	4.50	17.70	9.02	26.40
February	4.65	14.00	7.09	27.10
March	5.88	16.50	6.68	28.60
April	4.80	16.00	5.23	n/a
May	4.90	15.90	4.98	n/a
June	4.70	17.10		n/a
July	5.20	18.78	7.70	28.16
August	4.60	n/a	5.70	n/a
September	5.90	19.22	6.40	26.82
October	6.10	17.88	8.20	n/a
November	5.60	n/a	7.70	29.06
December	n/a	18.33	n/a	n/a
Annual Mean Wind Speed	5.70		6.79	
Annual MWh Equivalent	1,400		2,400	
Capacity Factor	0.16		0.27	

Average wind speed varys over the country but few detailed long- term records are available. Measurements have been taken at the top of a 100m high hill on a cliff-edge site at Lüderitz. This is not typical. Data at 30m mast from the proposed site will provide more realistic information.

The available data show that the highest wind speed is found along the coasts. It was deemed that, for example, the Walvis Bay and Lüderitz areas are promising. In the commercial farm areas, wind speed are too low for power generation. Wind speeds are lower still towards the north of the country.

There are data on wind speed for Pelican Point near Walvis Bay during the period 1964-1986. Its average wind speed is 4.29m/s for 23 years. It seems that a fairly low annual mean wind speed of 5.70m/s for Walvis Bay in Table 8.8 and it would be backed up by the figure 4.29m/s. Namibia seems to be a country where it generally is calm and it sometimes breezes.

d) Costs

A capital cost for FOB is around 900 to 1,000 US$/kW. An installation cost varies largely depending on the installation site and access roads, and is approximately 30 to 40% of capital cost. It is not possible to give a single estimate of the likely cost of a wind farm. An indicative capital cost for turnkey contracts to supply, install and commission a wind farm is 1,300 US$/kW.

The following figures are taken for a hypothetical installation in Walvis Bay and Lüderita:

Site	Walvis Bay	Lüderitz
Investment cost	1,300US$/kW	1,300US$/kW
Possible generation/MW	1,400MWh/year	2,400MWh/year
Capacity factor	0.16	0.27
Economic life	20years	20years
Yearly O&M cost	10% of capital cost	10% of capital cost
Total costs	9.6USc/kWh	6.6USc/kWh

Only above rough cost estimate can be given at this stage of being not provided with detailed wind information, when based on an interest rate of 7%. The indicative evaluation showed that wind energy utilization at both sites could not compete with a combined cycle electricity generation by Kudu gas even if taking into consideration transmission costs and losses to transfer Kudu power to both sites.

Generation cost of some 2USc/kWh can be expected with Kudu gas. Transmission costs and losses from Kudu is estimated to be around 1.4 USc/kW to Walvis Bay via new 400kV and 220kV lines and around 0.2USc/kWh to Lüderitz via an existing 66kV line between Oranjemund and Lüderitz.

Against projected delivering costs of around 3.4USc/kWh at Walvis Bay and 2.2USc/kW at Lüderitz from Kudu gas generation, the generatio costs from wind power at both sites are 9.6USc/kWh at Walvis Bay and 6.6USc/kWh at Lüderitz and severally around three times the delivering cost from Kudu.

This three-time difference would be too big to be covered with a cost reduction by expected advances in wind technology and detailed wind resources analysis including the installation of 30m mast, an accurate wind output estimation (1minute average wind measurement) and longer period logging.

The present assessment gives indications that wind power introduction in Namibia would not be economically justifiable at present and for quite some time. Namibia is generally and jealously calm without damage from a so-called cyclone.

CHAPTER 9

POWER DEVELOPMENT PLAN

CHAPTER 9 POWER DEVELOPMENT PLAN

9.1 Generation Expansion Alternative Options

There remains only three alternatives, which realistically may be considered for expansion of the generation system in the NamPower grid in the time horizon until 2020 in view of high fuel costs of coal and diesel oil and a prospect of a major market for renewable energy being off-grid.

- New 400kV interconnection with Eskom
- Kudu gas fired power generation
- Lower Cunene hydropower generation

Alternatives other than the above three are not considered for expansion for the following reasons:

Cost of coal, which is shipped over 3000km from RSA is very expensive, that is N$276.5/ton (1996 term, US$64.3/ton) at Van Eck plant or 2.3 US$/MBtu (See 4.1.3 Van Eck Thermal Power Plant). It's fuel cost of 3.65 USc/kWh is very high. The diesel oil price is N$1.45/liter (1996 term) at Paratus plant or 9.1 US$/MBtu. This implies it's fuel cost is 10.1 USc/kWh, if the thermal efficiency is assumed as 30.8%.

It is reported that Kudu gas field has sufficient proven reserves and there is the potential of further abundant gas. Considerable gas demand is foreseen and gas cost is expected to be less than 2 US$/MBtu. That is, fuel cost of less than 1.35 USc/kWh is expected. The natural gas is indigenous and clean energy source. Coal and oil could not compete with the natural gas in bulk generation.

The fact is that grants and subsidies have been given to alternatives considered as environmentally friendly, such as solar and wind energy. Grid connected solar and wind power remains economically unattractive in the whole Namibian supply alternative from a viewpoint of pursuing a minimum cost solution to contribute to Namibia's economic competitiveness. Where conventional rural electrification is impractical in terms of cost, the benefits from the use of photovoltaic systems can be considerable.

With regard to electricity import from SADC, the closest power resources from other than South Africa is Victoria Falls hydropower plant in Zambia. The distance between Victoria Falls and 220kV substation Otjikoto in Namibia is more than 1,000km. Assuming a connection with 400kV AC, it is necessary to reinforce the transmission network between Otjikoto and Gerus for reliability and real power loss purposes. Considering the additional cost for the transmission line investment and expected high losses, the disadvantage will be very clear.

An interconnection to Capanda hydropower in Angola is even more unrealistic. The distance from Capanda to lower Cunene River or Gerus is approximately 1,000km and 1,600km respectively.

Cahora Bassa hydropower project (1,450MW) in Mozambique has been reconstructed after the lapse of 20 years. However, it is reported that discussions between Portugal, Mozambique and South Africa have so far failed to reach consensus over tariffs, around 2.2 - 2.6 USc/kWh. The tariff of a large scale hydropower is not always very cheap. The transmission distance between Cahora Bassa and Windhoek is 3,500km, including 1,400km of 533kV DC line. Power consigning charge and losses in power wheeling would be tremendous and the project is further unrealistic to Namibia.

9.1.1 400kV Interconnection with Eskom

Whilst an increase in NamPower's generation capacity is a long term option, development and commissioning of a new plant would not be completed in time to prevent a shortfall. Furthermore, the existing transmission network is operating close to designed capacity and any additional generation capacity would require further investment in main high voltage transmission lines

Whilst NamPower is presently considering various alternatives to increase its generation capacity, the link with the South African network needs to be upgraded to provide capacity for both further imported power before new generation capacity can become available, but also to enable potential future exports to take place. The decision was therefore taken by NamPower to augment the existing 220kV link to Aggeneis on the Eskom grid by a 400kV line (Interconnector Project). It is now under construction.

The Interconnector Project involves the construction of approximately 900km of single circuit 400kV transmission line from Aries substation near Kenhardt in South Africa to the proposed Auas substation near Windhoek. The new line will pass through the existing 220kV Kokerboom substation, near Keetmanshoop, which will be extended to accommodate the 400kV circuits and associated transformers. The Project includes the construction of a new substation and the upgrading of an existing one in addition to the main transformer line. The transmission line will be constructed on a limited turnkey basis whereas NamPower will be responsible for implementation and construction related to the two substations.

The construction of the line will be completed in two phases. The first stage of the Project on the Namibian side involves the construction of the line from the border to Kokerboom and the extension of Kokerboom substation which should be completed by May 1999. The second stage, comprising the construction of the Auas substation near Windhoek and completion of the line from Kokerboom to Auas, is expected to be completed by May 2000 (Source: NamPower, 400kV Interconnector Project, October 1997).

Lead time	30 months (18 months for Phase 1)
Investment cost	209.2 MUS$ including 25.6 MUS$ of IDC
Disbursement	50%, 50%
Yearly O & M cost	1.8% of investment
Economic life	25 years

Transmission capacity

The following transmission capacity is decided according to design criteria of a new 400kV line (4x Tern for each phase) and the necessary installation of SVC (See Table 4.4).

First 400kV single circuit line	500MW
Existing 220kV double circuit line	340MW
Second 400kV single circuit line	500MW

Environmental issues

According to NamPower, a detailed Environmental Impact Assessment (EIA) study was completed by Walmsley Consultants in South Africa. All the relevant implications of the routing and construction of the proposed 400kV line were considered in this study. The methodology of the study closely follows the guidelines included in the national Environmental Assessment Policy. The study included the following steps:

- identification of environmentally sensitive areas and evaluation of alternatives
- public participation and feedback on issues arising
- environmental assessment of the selected power line route; and
- recommendations for the control and mitigation of any residual impacts

Generally the Project area was found not to be environmentally sensitive, however the transmission line route was selected specifically to accommodate all aspects of environmental concern. The same methodology can be applicable to transmission lines related to Epupa and Kudu projects.

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9.1.2 Kudu Gas Fired Power Generation

(1) Kudu Natural Gas Field

According to Shell Exploration and Production Namibia (SEPN) the Kudu gas field was first identified in 1974, in a water depth of approximately 170 m some 150 km off the coast from Oranjemund. During 1987 and 1988 two further wells confirmed the potential significance of the discovery. The gas-bearing reservoir (550 bar) is situated 4.5 km below sea level.

Shell and Engen of South Africa were awarded the exploration licence for the containing the Kudu gas in May 1993. They were recently joined by Texaco. SEPN is the operator of the project.

A detailed three-dimensional seismic survey, covering 300 km^2 around the Kudu wells was conducted in 1993. Following encouragement from the evaluation of the 3D seismic data and the gas market development studies, the Kudu-4 exploration well was drilled in 1996, confirming a significant energy resource in Namibian water.

After extensive follow-up studies by a subsequent production test, SEPN applied for the declaration of a petroleum field for all of the licence area in May 1997 and the application has subsequently been approved by the MME.

Further according to SEPN, sufficient gas is present in the Kudu gas field for an initial development supplying a potential market in Namibia. Approximately 1.8 TCF (50,000 million m^3) gas volume in place is considered to be proven. A similar volume is expected in the area around the Kudu gas field covered by the 300 km^2 3D seismic survey, while further scope for volume in place in excess of 5 TCF (140,000 million m^3) are estimated in the remainder of the Kudu licence area covering more than 5,000 km^2.

Parallel to the initial development phase, a second phase aimed at a large gas export scheme for the supply for gas to power and industrial markets in South Africa for which gas market development effort give encouraging indications is to be pursued.

While there is sufficient confidence on the gas volumes required for the initial development phase, further exploratory appraisal drilling is planned to prove the additional gas necessary for the next development phase. Such drilling may take place in the area of the 400 km^2 3D seismic survey carried out in 1996/97 adjacent to the Kudu field area. Preparations are being made to enable drilling to start in the second half of 1998.

The present proven volumes of 50, 000 million m^3 are more than sufficient for initial development of the Kudu gas field to supply 750MW requiring 2.4 million m^3/day over a 50-year period as shown below.

1 kWh = 3.6 MJ Gas heating content = 37.3 MJ/m^3

Net plant heat rate (HHV) = 7100 kJ/kWh (η = 50.7%)

Annual generation = 750 MW x 8760h x 0.7 = 4600GWh/year

Annual gas consumption = 4600 x 7.1/37.3 $\fallingdotseq$ 900 Mm^3/year

Longevity = 50 000 Mm^3/900 = 55 years

Proven recoverable reserves at this stage total 1.8 TCF, with an exploitable probability of 85% to 90% and probable reserves of 1.8 TCF, with the probability of 50% may usually be used for a planning. Another 5 TCF possible reserves are estimated with the probability of 15%, which is too low to be used for it. This is of SEPN's opinion.

The reserves will require drilling of production wells and construction of an undersea gathering and transport pipeline system. The gas is under sufficient geologic pressure to provide pipeline transport to shore without the need for supplemental compression. The gas so far has a high methane content and a heating content of 37.3 MJ per cubic meter.

A large scale development of the Kudu gas would be thus be possible and also most profitable due to economics of scale, but only if a market for the gas could be established. Among those interested in buying gas from the Kudu field are the likes of South Africa's Saldanah Steel for its Corex plant, Industrial Development Corp for a gas-based iron plant and Eskom for its power station.

Namibian government decided to attract private investment for petroleum exploration and passed petroleum related acts in 1991. The MME recognises the importance of the Kudu gas field and is making efforts on a political level to secure a market in the region.

A memorandum of understanding on trade in natural gas was signed between the MME and South African government in November 1997. This is to pave the way for a bilateral gas trade agreement. The MOU will direct the two ministries to discuss all relevant issues concerning gas, including markets, pipelines, financial, legal, regulatory and environmental issues. These negotiations will result in a bi-national gas trade agreement between Namibia and South Africa. There is enough evidence to indicate sufficient potential demand within the region. Thus gas price of less than 2 US$/MBtu (oil equivalent 12 US$/bbl) could be expected.

(2) Combined Cycle Gas Turbine Plant

Phased output and cost

The most advanced type 1300°C class combined cycle gas turbine (CCGT) offers maximum reliability, efficiency and economy. It is also highly flexible on cycle configuration, fuel selection and site adaptation. 750MW CCGT is considered to be adequate to NamPower's system expansion. It comprises one CCGT generation block (2x1 configuration) that includes two gas turbine generator machines and one steam turbine generator unit. Phased outputs are assumed as follows:

	Net output	Efficiency(HHV)	Cost
One gas turbine	250MW	33.8%	25%
Two gas turbines	500MW	33.8%	50%
Configuration to CCGT	750MW	50.7%	100%

<u>CCGT plant site</u>

This is a matter of transportation of gas or electricity. Cost of gas supply pipeline of 50cm ϕ would be around 270,000~360,000 US$/km. On the other hand that of 400kV electricity transmission line is around 180,000 US$/km. The transmission capacity depends on a distance and various conditions. Approximately 400~500km will be a limit to send 750MW with 400kV line under the conditions of successful reclosing a single phase ground fault. 400kV line transmission is apparently advantageous as long as the single line can be used. For this reason the Oranjemund region near the mouth of the Orange River which gives the shortest distance of gas supply line would be the most desirable site. The technical and economic evaluation is based on the plant location around Oranjemund.

<u>Related transmission lines</u>

A new 400kV transmission line related to the CCGT plant is assumed for its integration into the NamPower grid. The routing would be almost on a direct alignment from Oranjemund plant site to Kokerboom substation partly along Route 463, based on a reconnaissance of the JICA study team. A distance of the routing is approximately 350km.

One 400kV line could withstand a single line to ground fault with successful reclosing under a 750MW load, with corrective action if needed. Preliminary investigations show a 750MW plant size would be instable against three phase fault to ground assuming reclosing. This matter requires detailed system analyses.

Cost of combined cycle power generation

Gas turbine generator prices are market driven and the market is currently very competitive. Total plant unit cost of @440 US$/kW can be expected. Prices for a block of CCGT and a 400kV line of 350km have been assumed based on the past records for investments and operation as follows:

Lead time	28 months
Total investment cost	406 MUS$ including 31MUS$ of IDC
(Power plant)	334 MUS$ including 26 MUS$ of IDC
(Transmission system)	72 MUS$ including 5 MUS$ of IDC
Disbursement	50%, 50%
Fixed O & M cost	5 US$/kW/year
Variable O & M cost	0.2 USc/kWh
Natural gas cost	1.6 US$/MBtu
Economic life	20 years

A pre-feasibility study for combined cycle plant was already completed in April 1997 and a feasibility study is in progress, but they are not available to the Study Team. Also information on generation mix, and its costing and finance is confidential and not available to the Study Team.

Environmental issues

Kudu natural gas appears very clean without H_2S content. The site would be located within the austere desert region known as the Diamond Area 1 and an area of low environmental sensitivity and be sparsely inhabited. NamPower is in preparation for EIA study.

The planned CCGT plant has remarkably high efficiency of 50.7%. This means quite a lower fuel consumption compared with a conventional thermal plant with efficiency of around 38% and also very much preferable from a viewpoint of energy conservation.

9.1.3 Lower Cunene Hydropower Scheme

The draft feasibility study report was delivered in October 1997 to compare the Epupa (former Epupa scheme B) and Baynes alternatives. With the Gove dam in operation the Epupa project is somewhat better than the Baynes project with regard to generation, the present value of system cost (PVSC) and EIRR. The economic comparison is made about the Epupa scheme which is more viable.

The hydropower schemes require a huge investment and long lead time. It would be practical to consider the lead time as nine to ten years which include application for loan, the appraisal, exchange of note, loan agreement, selection of consultant and tender.

Epupa Scheme Major Data (Source: Lower Cunene Hydro F.S.)

Reservoir total volume	11 500 million m^3
Reservoir active storage	7 800 million m^3
Available draw down	30 m
Type of dam wall	Concrete arch gravity
Dam wall height	163 m
Annual electricity production	(Base case)
with Gove Dam	1 730 GWh
without Gove Dam	1 724 GWh
Power station installed capacity	360 MW
Lead time	9~10 years
Transmission lines	330kV, 663km long (91.5 MUS$)
Total project construction cost	695 MUS$ including 155.6 MUS$ of IDC
Inundated area (high water)	380 km^2
No. of permanent users effected	±1 000
Number of inundated graves	160 identified

Probable problem areas

NamPower Chairman formally mentions in its annual report 1997 that the viability study for a hydro-electric scheme on the lower reaches of the Cunene River to be shared on a 50-50 basis with Angola has been tabled.

Feasibility study on lower Cunene hydropower scheme has been worked out on the assumption that all hydro-energy produced can be used in Namibia. It is unlikely for the time being that Cunene hydropower be partly transferred in view of the political situation, economic conditions and the energy situation in Angola.

However, in a long term span the assessment of the hydropower scheme in this report is likely to be impaired without reasonable sharing of the costs by the Angolan side. This is the biggest uncertainties at the moment in the hydropower scheme.

The year to year and annual variation of the Cunene river is considerable, the most serious circumstance being relatively long period of drought, recorded as lasting for several years (Refer to subsection 4.1.2). This will imply that the output and income of the hydro-plant also fluctuate and are unreliable in the technical and financial terms.

Cost and time overruns due to uncertainties are not rare in a hydropower project, associated with hydrology, geology and many site-specific elements.

Relocation and compensation problems are critical issues in cultural as well as socio-economic contexts. Namibia's Ovahimba communities who live in the Epupa area have flatly rejected the proposed scheme.

The Cunene hydropower generation is clean and renewable energy except for impact on human, physical and living environment, but should be deemed to be **semi-indigenous** now. It might be natural as an international river.

9.2 National Energy Policy on Enhanced Security of Supply

The draft White Paper on the Energy Policy of Namibia describes the following in its 3.1.4.1 Enhanced security of supply:

"- - - - - It is important that the economic merits and risks associated with local generation options are compared against the alternative of importing electricity.

> *Electricity supply in Namibia shall be based on a balance of economically efficient and sustainable electricity sources including gas, hydro-power, other renewable energy sources and imported electricity.*
>
> - - - - -

Although Namibia's resources are more than sufficient to meet future electricity demands, it is important that the cost and efficiency of internal resource utilisation is compared to imports as an alternative. This will ensure not only rational economic resource utilisation to the benefit of electricity consumers in Namibia, but also improved security of supply through diversification of the electricity supply base. Duly considering associated risks, it is the aim of Government that 100% of the peak demand and at least 75% of the electric energy demand will be supplies from internal sources by 2010. - - - - -"

The above has carefully been taken into account in setting up the power development plan.

9.3 Definition of Scenarios

The five scenarios presented below have been defined for economic/technical evaluation and comparison after numerous preliminary investigations which clearly showed that each of them constitutes the least cost solution of its kind in the mix of a theme alternative and the other two options. This will inevitably create a kind of the best mix of energy.

- Scenario A Self sufficiency - CCGT
- Scenario B Self sufficiency - Hydropower
- Scenario C Business as usual - Extended import
- Scenario D Business as usual - CCGT
- Scenario E Business as usual - Hydropower

The self sufficiency scenarios will aim at realisation of the energy policy (draft) that 100% of the peak demand and at least 75% of the electricity demand will be supplied from internal sources by 2010. The business as usual scenarios will pursue the most economic measures, being free from the 100% peak target.

9.4 Addition of Electrical Facilities

An addition of electrical facilities has been designed to meet the demand forecast presented in Chapter 6 Electrical demand forecast. It is considered that power utilities should provide a supply capability with sufficient system margin against the moderate growth and a supply capacity at any rate against the high growth in view of self sufficiency. However, NamPower will remain on favorable ground to be able to rely on Eskom in an emergency. The addition is planned for in-country use only till the year 2008, when it is anticipated that Eskom's excess generation capacity will be digested.

A summary of additions in alternative scenarios is presented in Table 9.1.

Table 9.1 Summary of Additions in Alternative Scenarios

Scenario / Year	Self Sufficiency		Business As Usual		
	A. CCGT	B. Hydro	C. Import	D. CCGT	E. Hydro
1997					
1998					
1999	400kV line-1 Aries-Koker.	400kV line-1 Aries-Koker.	400kV line-1 Aries-Koker.	400kV line-1 Aries-Koker.	400kV line-1 Aries-Koker.
2000	400kV line-1 Koker.-Auas	400kV line-1 Koker.-Auas	400kV line-1 Koker.-Auas	400kV line-1 Koker.-Auas	400kV line-1 Koker.-Auas
2001					
2002	CCGT-1	CCGT-1	CCGT-1	CCGT-1	CCGT-1
2003					
2004					
2005					
2006					
2007					
2008		Epupa Hydro			
2009					
2010	CCGT-2	(2xGT)			
2011					
2012					
2013				CCGT-2	Epupa Hydro
2014	CCGT-3	Configurate to CCGT-2	400kV line-2		
2015					
2016					
2017					(2xGT)
2018		(2xGT)			
2019					
2020					

Note: The additions are to be completed by May of the year.

9.4.1 Capacity Balance

A capacity balance is presented in the tables below for the moderate and high growth cases in the five scenarios. The firm capacity of the system at a peaking time should be over the maximum demand forecast. The peak load usually occurs in June or July, when it is in the midst of the dry season. It should be noted that Ruacana firm capacity can be nearly zero during a dry year against the installed capacity of 240MW. Epupa firm capacity is estimated to be around 300MW at lower water level of the reservoir against the installed capacity of 360MW.

<u>Power import limitations</u>

As described under 9.1.1- Item: Transmission capacity it is assumed that power import from Eskom may be extended up to 840MW by the first 400kV line completion.

First 400kV line	500MW
Existing 220kV line	340MW
Second 400kV line	500MW

<u>Van Eck and Paratus thermal power plants</u>

It is assumed that Van Eck and Paratus thermal plants will be not in operation because of their high fuel costs. The two plants are not incorporated in the capacity and energy balance. However, it is worth maintaining them. They can be of use in reducing firm capacity charge from Eskom and Van Eck can be used as a synchronous phase modifier for line voltage regulation.

<u>Peak load in National grid</u>

20MW has been subtracted from the forecast maximum demand under Chapter 6 because it includes Orajemund, Rosh Pinah, Noordoewer and Ariamsvlei supplied from Eskom and Katima Mulilo supplied from Zambia.

Table 9.2 Scenario A Self Sufficiency-CCGT

Capacity Balance [MW]

Year	Addition	Moderate growth		High growth	
		Peak load	Available capacity (Presumable import) [Desirable export]	Peak load	Available capacity (Presumable import) [Desirable export]
1999	**400kV line Arles-Kokerbo.**	393	Import 460 (393) Ruacana 0	400	Import 460 (400) Ruacana 0
2000	**400kV line Kokerbo.-Auas**	477	Import 840 (477) Ruacana 0	634	Import 840 (634) Ruacana 0
2001		522	Import 840 (522) Ruacana 0	815	Import 840 (815) Ruacana 0
2002	**CCGT Block 1 (+400kV line)**	542	Import 840 (0) Ruacana 0 CCGT 750	855	Import 840 (105) Ruacana 0 CCGT 750
2003		563	Import 840 (0) Ruacana 0 CCGT 750	883	Import 840 (133) Ruacana 0 CCGT 750
2004		584	Import 840 (0) Ruacana 0 CCGT 750	911	Import 840 (161) Ruacana 0 CCGT 750
2005		609	Import 840 (0) Ruacana 0 CCGT 750	962	Import 840 (212) Ruacana 0 CCGT 750
2006		672	Import 840 (0) Ruacana 0 CCGT 750	1052	Import 840 (302) Ruacana 0 CCGT 750
2007		732	Import 840 (0) Ruacana 0 CCGT 750	1140	Import 840 (390) Ruacana 0 CCGT 750
2008		755	Import 840 (0) Ruacana 0 CCGT 750	1192	Import 840 (442) Ruacana 0 CCGT 750
2009		779	Import 840 (0) Ruacana 0 CCGT 750	1228	Import 840 (478) Ruacana 0 CCGT 750
2010	**CCGT Block 2 (+400kV line)**	806	Import 840 (0) Ruacana 0 2xCCGT 1500 [694]	1267	Import 840 (0) Ruacana 0 2xCCGT 1500 [233]
2011		836	Import 840 (0) Ruacana 0 2xCCGT 1500 [664]	1312	Import 840 (0) Ruacana 0 2xCCGT 1500 [188]
2012		862	Import 840 (0) Ruacana 0 2xCCGT 1500 [638]	1375	Import 840 (0) Ruacana 0 2xCCGT 1500 [125]
2013		889	Import 840 (0) Ruacana 0 2xCCGT 1500 [611]	1474	Import 840 (0) Ruacana 0 2xCCGT 1500 [26]
2014	**CCGT Block 3 (+400kV line)**	917	Import 840 (0) Ruacana 0 3xCCGT 2250 *[840]	1591	Import 840 (0) Ruacana 0 3xCCGT 2250 [659]
2015		946	Import 840 (0) Ruacana 0 3xCCGT 2250 *[840]	1677	Import 840 (0) Ruacana 0 3xCCGT 2250 [573]

2016		978	Import 840 (0) Ruacana 0 3xCCGT 2250 *[840]	1733	Import 840 (0) Ruacana 0 3xCCGT 2250 [517]
2017		1005	Import 840 (0) Ruacana 0 3xCCGT 2250 *[840]	1786	Import 840 (0) Ruacana 0 3xCCGT 2250 [464]
2018		1033	Import 840 (0) Ruacana 0 3xCCGT 2250 *[840]	1841	Import 840 (0) Ruacana 0 3xCCGT 2250 [409]
2019		1062	Import 840 (0) Ruacana 0 3xCCGT 2250 *[840]	1937	Import 840 (0) Ruacana 0 3xCCGT 2250 [313]
2020		1092	Import 840 (0) Ruacana 0 3xCCGT 2250 *[840]	2042	Import 840 (0) Ruacana 0 3xCCGT 2250 [208]

Ref. *: Power export limitation to interconnector capacity

Table 9.3 Scenario B Self Sufficiency-Hydropower

Capacity Balance[MW]

Year	Addition	Moderate growth		High growth	
		Peak load	Available capacity (Presumable import) [Desirable export]	Peak load	Available capacity (Presumable import) [Desirable export]
1999	**400kV line Aries-Kokerbo.**	393	Import 460 (393) Ruacana 0	400	Import 460 (400) Ruacana 0
2000	**400kV line Kokerbo.-Auas**	477	Import 840 (477) Ruacana 0	634	Import 840 (634) Ruacana 0
2001		522	Import 840 (522) Ruacana 0	815	Import 840 (815) Ruacana 0
2002	**CCGT Block 1 (+400kV line)**	542	Import 840 (0) Ruacana 0 CCGT 750	855	Import 840 (105) Ruacana 0 CCGT 750
2003		563	Import 840 (0) Ruacana 0 CCGT 750	883	Import 840 (133) Ruacana 0 CCGT 750
2004		584	Import 840 (0) Ruacana 0 CCGT 750	911	Import 840 (161) Ruacana 0 CCGT 750
2005		609	Import 840 (0) Ruacana 0 CCGT 750	962	Import 840 (212) Ruacana 0 CCGT 750
2006		672	Import 840 (0) Ruacana 0 CCGT 750	1052	Import 840 (302) Ruacana 0 CCGT 750
2007		732	Import 840 (0) Ruacana 0 CCGT 750	1140	Import 840 (390) Ruacana 0 CCGT 750
2008	**Epupa Hydro (+330kV line)**	755	Import 840 (0) Ruacana 0 CCGT 750 Epupa 300	1192	Import 840 (142) Ruacana 0 CCGT 750 Epupa 300
2009		779	Import 840 (0) Ruacana 0 CCGT 750 Epupa 300	1228	Import 840 (178) Ruacana 0 CCGT 750 Epupa 300
2010	**2 gas turbines of CCGT Block 2 (+400kV line)**	806	Import 840 (0) Ruacana 0 CCGT 750 [244] Epupa 300 2xGT 500 [500]	1267	Import 840 (0) Ruacana 0 CCGT 750 Epupa 300 2xGT 500 [283]
2011		836	Import 840 (0) Ruacana 0 CCGT 750 [214] Epupa 300 2xGT 500 [500]	1312	Import 840 (0) Ruacana 0 CCGT 750 Epupa 300 2xGT 500 [238]
2012		862	Import 840 (0) Ruacana 0 CCGT 750 [188] Epupa 300 2xGT 500 [500]	1375	Import 840 (0) Ruacana 0 CCGT 750 Epupa 300 2xGT 500 [175]
2013		889	Import 840 (0) Ruacana 0 CCGT 750 [161] Epupa 300 2xGT 500 [500]	1474	Import 840 (0) Ruacana 0 CCGT 750 Epupa 300 2xGT 500 [76]

2014	**CCGT Block 2 (+400kV line)**	917	Import 840 (0) Ruacana 0 2xCCGT 1500 *[840] Epupa 300	1591	Import 840 (0) Ruacana 0 2xCCGT 1500 [209] Epupa 300
2015		946	Import 840 (0) Ruacana 0 2xCCGT 1500 *[840] Epupa 300	1677	Import 840 (0) Ruacana 0 2xCCGT 1500 [123] Epupa 300
2016		978	Import 840 (0) Ruacana 0 2xCCGT 1500 [822] Epupa 300	1733	Import 840 (0) Ruacana 0 2xCCGT 1500 [67] Epupa 300
2017		1005	Import 840 (0) Ruacana 0 2xCCGT 1500 [795] Epupa 300	1786	Import 840 (0) Ruacana 0 2xCCGT 1500 [14] Epupa 300
2018	**2 gas turbines of CCGT Block 3 (+400kV line)**	1033	Import 840 (0) Ruacana 0 2xCCGT 1500 [767] Epupa 300 2xGT 500 *[73]	1841	Import 840 (0) Ruacana 0 2xCCGT 1500 Epupa 300 [459] 2xGT 500
2019		1062	Import 840 (0) Ruacana 0 2xCCGT 1500 [748] Epupa 300 2xGT 500 *[92]	1937	Import 840 (0) Ruacana 0 2xCCGT 1500 Epupa 300 [363] 2xGT 500
2020		1092	Import 840 (0) Ruacana 0 2xCCGT 1500 [708] Epupa 300 2xGT 500 * [132]	2042	Import 840 (0) Ruacana 0 2xCCGT 1500 Epupa 300 [258] 2xGT 500

Table 9.4 Scenario C Business As Usual-Extended Import

Capacity Balance[MW]

Year	Addition	Moderate growth		High growth	
		Peak load	Available capacity (Presumable import)	Peak load	Available capacity (Presumable import)
1999	**400kV line Aries-Kokerbo.**	393	Import 460 (393) Ruacana 0	400	Import 460 (400) Ruacana 0
2000	**400kV line Kokerbo.-Auas**	477	Import 840 (477) Ruacana 0	634	Import 840 (634) Ruacana 0
2001		522	Import 840 (522) Ruacana 0	815	Import 840 (815) Ruacana 0
2002	**CCGT Block 1 (+400kV line)**	542	Import 840 (0) Ruacana 0 CCGT 750	855	Import 840 (105) Ruacana 0 CCGT 750
2003		563	Import 840 (0) Ruacana 0 CCGT 750	883	Import 840 (133) Ruacana 0 CCGT 750
2004		584	Import 840 (0) Ruacana 0 CCGT 750	911	Import 840 (161) Ruacana 0 CCGT 750
2005		609	Import 840 (0) Ruacana 0 CCGT 750	962	Import 840 (212) Ruacana 0 CCGT 750
2006		672	Import 840 (0) Ruacana 0 CCGT 750	1052	Import 6840 (302) Ruacana 0 CCGT 750
2007		732	Import 840 (0) Ruacana 0 CCGT 750	1140	Import 840 (390) Ruacana 0 CCGT 750
2008		755	Import 840 (5) Ruacana 0 CCGT 750	1192	Import 840 (442) Ruacana 0 CCGT 750
2009		779	Import 840 (29) Ruacana 0 CCGT 750	1228	Import 840 (478) Ruacana 0 CCGT 750
2010		806	Import 840 (56) Ruacana 0 CCGT 750	1267	Import 840 (517) Ruacana 0 CCGT 750
2011		836	Import 840 (86) Ruacana 0 CCGT 750	1312	Import 840 (562) Ruacana 0 CCGT 750
2012		862	Import 840 (112) Ruacana 0 CCGT 750	1375	Import 840 (625) Ruacana 0 CCGT 750
2013		889	Import 840 (139) Ruacana 0 CCGT 750	1474	Import 840 (724) Ruacana 0 CCGT 750
2014	**2nd 400KV line**	917	Import 1340 (167) Ruacana 0 CCGT 750	1591	Import 1340 (841) Ruacana 0 CCGT 750
2015		946	Import 1340 (196) Ruacana 0 CCGT 750	1677	Import 1340 (927) Ruacana 0 CCGT 750

2016		978	Import Ruacana CCGT	1340 0 750	(228)	1733	Import Ruacana CCGT	1340 0 750	(983)
2017		1005	Import Ruacana CCGT	1340 0 750	(255)	1786	Import Ruacana CCGT	1340 0 750	(1036)
2018		1033	Import Ruacana CCGT	1340 0 750	(283)	1841	Import Ruacana CCGT	1340 0 750	(1091)
2019		1062	Import Ruacana CCGT	1340 0 750	(312)	1937	Import Ruacana CCGT	1340 0 750	(1187)
2020		1092	Import Ruacana CCGT	1340 0 750	(342)	2042	Import Ruacana CCGT	1340 0 750	(1292)

Table 9.5 Scenario D Business As Usual-CCGT

Capacity Balance[MW]

Year	Addition	Moderate growth		High growth	
		Peak load	Available capacity (Presumable import) [Desirable export]	Peak load	Available capacity (Presumable import) [Desirable export]
1999	**400kV line Aries-Kokerbo.**	393	Import 460 (393) Ruacana 0	400	Import 460 (400) Ruacana 90
2000	**400kV line Kokerbo.-Auas**	477	Import 840 (477) Ruacana 0	634	Import 840 (634) Ruacana 0
2001		522	Import 840 (522) Ruacana 0	815	Import 840 (815) Ruacana 0
2002	**CCGT Block 1 (+400kV line)**	542	Import 840 (0) Ruacana 0 CCGT 750	855	Import 840 (105) Ruacana 0 CCGT 750
2003		563	Import 840 (0) Ruacana 0 CCGT 750	883	Import 840 (133) Ruacana 0 CCGT 750
2004		584	Import 840 (0) Ruacana 0 CCGT 750	911	Import 840 (161) Ruacana 0 CCGT 750
2005		609	Import 840 (0) Ruacana 0 CCGT 750	962	Import 840 (212) Ruacana 0 CCGT 750
2006		672	Import 840 (0) Ruacana 0 CCGT 750	1052	Import 840 (302) Ruacana 0 CCGT 750
2007		732	Import 840 (0) Ruacana 0 CCGT 750	1140	Import 840 (390) Ruacana 0 CCGT 750
2008		755	Import 840 (5) Ruacana 0 CCGT 750	1192	Import 840 (442) Ruacana 0 CCGT 750
2009		779	Import 840 (29) Ruacana 0 CCGT 750	1228	Import 840 (478) Ruacana 0 CCGT 750
2010		806	Import 840 (56) Ruacana 0 CCGT 750	1267	Import 840 (517) Ruacana 0 CCGT 750
2011		836	Import 840 (86) Ruacana 0 CCGT 750	1312	Import 840 (562) Ruacana 0 CCGT 750
2012		862	Import 840 (112) Ruacana 0 CCGT 750	1375	Import 840 (625) Ruacana 0 CCGT 750
2013	**CCGT Block 2**	889	Import 840 (0) Ruacana 0 2xCCGT 1500 [611]	1474	Import 840 (0) Ruacana 0 2xCCGT 1500 [26]
2014		917	Import 840 (0) Ruacana 0 2xCCGT 1500 [583]	1591	Import 840 (91) Ruacana 0 2xCCGT 1500
2015		946	Import 840 (0) Ruacana 0 2xCCGT 1500 [554]	1677	Import 840 (177) Ruacana 0 2xCCGT 1500

2016		978	Import 840 (0) Ruacana 0 2xCCGT 1500 [522]	1733	Import 840 (233) Ruacana 0 2xCCGT 1500
2017		1005	Import 840 (0) Ruacana 0 2xCCGT 1500 [495]	1786	Import 840 (286) Ruacana 0 2xCCGT 1500
2018		1033	Import 840 (0) Ruacana 0 2xCCGT 1500 [467]	1841	Import 840 (341) Ruacana 0 2xCCGT 1500
2019		1062	Import 840 (0) Ruacana 0 2xCCGT 1500 [438]	1937	Import 840 (437) Ruacana 0 2xCCGT 1500
2020		1092	Import 840 (0) Ruacana 0 2xCCGT 1500 [408]	2042	Import 840 (542) Ruacana 0 2xCCGT 1500

Table 9.6 Scenario E Business As Usual-Hydropower

Capacity Balance[MW]

Year	Addition	Moderate growth		High growth	
		Peak load	Available capacity (Presumable import) [Desirable export]	Peak load	Available capacity (Presumable import) [Desirable export]
1999	**400kV line Aries-Kokerbo.**	393	Import 460 (393) Ruacana 0	400	Import 460 (400) Ruacana 0
2000	**400kV line Kokerbo.-Auas**	477	Import 840 (477) Ruacana 0	634	Import 840 (634) Ruacana 0
2001		522	Import 840 (522) Ruacana 0	815	Import 840 (815) Ruacana 0
2002	**CCGT Block 1 (+400kV line)**	542	Import 840 (0) Ruacana 0 CCGT 750	855	Import 840 (105) Ruacana 0 CCGT 750
2003		563	Import 840 (0) Ruacana 0 CCGT 750	883	Import 840 (133) Ruacana 0 CCGT 750
2004		584	Import 840 (0) Ruacana 0 CCGT 750	911	Import 840 (161) Ruacana 0 CCGT 750
2005		609	Import 840 (0) Ruacana 0 CCGT 750	962	Import 840 (212) Ruacana 0 CCGT 750
2006		672	Import 840 (0) Ruacana 0 CCGT 750	1052	Import 840 (302) Ruacana 0 CCGT 750
2007		732	Import 840 (0) Ruacana 0 CCGT 750	1140	Import 840 (390) Ruacana 0 CCGT 750
2008		755	Import 840 (5) Ruacana 0 CCGT 750	1192	Import 840 (442) Ruacana 0 CCGT 750
2009		779	Import 840 (29) Ruacana 0 CCGT 750	1228	Import 840 (478) Ruacana 0 CCGT 750
2010		806	Import 840 (56) Ruacana 0 CCGT 750	1267	Import 840 (517) Ruacana 0 CCGT 750
2011		836	Import 840 (86) Ruacana 0 CCGT 750	1312	Import 840 (562) Ruacana 0 CCGT 750
2012		862	Import 840 (112) Ruacana 0 CCGT 750	1375	Import 840 (625) Ruacana 0 CCGT 750
2013	**Epupa Hydro (+330kV line)**	889	Import 840 (0) Ruacana 0 CCGT 750 [161] Epupa 300	1474	Import 840 (424) Ruacana 0 CCGT 750 Epupa 300
2014		917	Import 840 (0) Ruacana 0 CCGT 750 [133] Epupa 300	1591	Import 840 (541) Ruacana 0 CCGT 750 Epupa 300
2015		946	Import 840 (0) Ruacana 0 CCGT 750 [104] Epupa 300	1677	Import 840 (627) Ruacana 0 CCGT 750 Epupa 300

2016		978	Import Ruacana CCGT Epupa	840 0 750 300	(0) [72]	1733	Import Ruacana CCGT Epupa	840 0 750 300	(683)
2017	**2 gas turbines of CCGT Block 2 (+400kV line)**	1005	Import Ruacana CCGT Epupa 2xGT	840 0 750 300 500	(0) [45] [500]	1786	Import Ruacana CCGT Epupa 2xGT	840 0 750 300 500	(236)
2018		1033	Import Ruacana CCGT Epupa 2xGT	840 0 750 300 500	(0) [17] [500]	1841	Import Ruacana CCGT Epupa 2xGT	840 0 750 300 500	(291)
2019		1062	Import Ruacana CCGT Epupa 2xGT	840 0 750 300 500	(0) [488]	1937	Import Ruacana CCGT Epupa 2xGT	840 0 750 300 500	(387)
2020		1092	Import Ruacana CCGT Epupa 2xGT	840 0 750 300 500	(0) [458]	2042	Import Ruacana CCGT Epupa 2xGT	840 0 750 300 500	(492)

9.4.2 Energy Balance

Total sent out energy has been calculated by the forecast electricity sales under Chapter 6 less 100GWH (non-interconnected supplies) plus 12% of transmission losses. Energy balance is filled in the cheapest running order. Namely, hydropower plants are first operated, and then Kudu CCGT, and finally import from Eskom.

Energy balance for moderate growth and high growth in the five scenarios has been made for economic evaluation.

It should be noted that annual energy production of a hydropower plant will largely fluctuate (more than ten times) although energy balance has been filled with average annual generation.

Table 9.7 Scenario A Self Sufficiency-CCGT

Energy Balance[GWh] Moderate Growth

Year	Energy Forecast	Total Sent out	Supply				Export
			Kudu	Ruacana	Epupa	Import	
1999	2061.5	2196	0	1055		1141	
2000	2495.8	2683	0	1055		1628	
2001	2716.5	2930	0	1055		1875	
2002	2804.4	3029	1002	1055		972	
2003	2894.0	3129	2074	1055		0	
2004	2984.7	3231	2176	1055		0	
2005	3092.5	3352	2297	1055		0	
2006	3409.7	3707	2652	1055		0	
2007	3714.2	4048	2993	1055		0	
2008	3814.7	4160	3090	1055		15	
2009	3919.4	4278	3133	1055		90	
2010	4033.6	4406	3351	1055		0	4256
2011	4168.1	4556	3501	1055		0	4072
2012	4280.7	4682	3627	1055		0	3912
2013	4396.3	4812	3757	1055		0	3747
2014	4515.2	4945	3890	1055		0	5150
2015	4643.0	5088	4033	1055		0	5150
2016	4783.1	5245	4190	1055		0	5150
2017	4903.6	5379	4324	1055		0	5150
2018	5025.8	5517	4462	1055		0	5150
2019	5153.1	5659	4604	1055		0	5150
2020	5283.3	5805	4750	1055			5150

Energy Balance[GWh] High Growth

Year	Energy Forecast	Energy Sent Out	Supply				Export
			Kudu	Ruacana	Epupa	Import	
1999	2099.3	2239	0	1055		1184	
2000	3469.3	3773	0	1055		2718	
2001	4407.2	4824	0	1055		3769	
2002	4733.4	5189	2291	1055		1843	
2003	4850.7	5321	3866	1055		400	
2004	4973.4	5458	3923	1055		480	
2005	5227.0	5742	4047	1055		640	
2006	5697.0	6269	4304	1055		910	
2007	6154.8	6781	4556	1055		1170	
2008	6413.4	7071	4686	1055		1330	
2009	6568.7	7245	4760	1055		1430	
2010	6739.0	7436	6381	1055		0	1429
2011	6936.5	7657	6602	1055		0	1153
2012	7254.1	8012	6957	1055		0	767
2013	7790.2	8613	7558	1055		0	159
2014	8431.3	9331	8276	1055		0	4041
2015	8871.2	9824	8769	1055		0	3514
2016	9118.8	10101	9040	1055		0	3169
2017	9351.9	10362	9307	1055		0	2844
2018	9592.9	10632	9577	1055		0	2507
2019	10091.2	11190	10135	1055		0	1919
2020	10647.4	11813	10758	1055		0	1275

Table 9.8 Scenario B Self Sufficiency-Hydro

Energy Balance[GWh] Moderate Growth

Year	Energy Forecast	Total Sent out	Supply				Export
			Kudu	Ruacana	Epupa	Import	
1999	2061.5	2196	0	1055		1141	
2000	2495.8	2683	0	1055		1628	
2001	2716.5	2930	0	1055		1875	
2002	2804.4	3029	1002	1055		972	
2003	2894.0	3129	2074	1055		0	
2004	2984.7	3231	2176	1055		0	
2005	3092.5	3352	2297	1055		0	
2006	3409.7	3707	2652	1055		0	
2007	3714.2	4048	2993	1055		0	
2008	3814.7	4160	1375	1055	1730	0	
2009	3919.4	4278	1493	1055	1730	0	
2010	4033.6	4406	1621	1055	1730	0	4546
2011	4168.1	4556	1771	1055	1730	0	4377
2012	4280.7	4682	1897	1055	1730	0	4217
2013	4396.3	4812	2027	1055	1730	0	4052
2014	4515.2	4945	2200	1055	1730	0	5149
2015	4643.0	5088	2303	1055	1730	0	5149
2016	4783.1	5245	2460	1055	1730	0	5039
2017	4903.6	5379	2594	1055	1730	0	4873
2018	5025.8	5517	2732	1055	1730	0	5150
2019	5153.1	5659	2874	1055	1730	0	5150
2020	5283.3	5805	3020	1055	1730	0	5150

Energy Balance[GWh] High Growth

Year	Energy Forecast	Energy Sent Out	Supply				Export
			Kudu	Ruacana	Epupa	Import	
1999	2099.3	2239	0	1055		1184	
2000	3469.3	3773	0	1055		2718	
2001	4407.2	4824	0	1055		3769	
2002	4733.4	5189	2291	1055		1843	
2003	4850.7	5321	3866	1055		400	
2004	4973.4	5458	3923	1055		480	
2005	5227.0	5742	4047	1055		640	
2006	5697.0	6269	4304	1055		910	
2007	6154.8	6781	4556	1055		1170	
2008	6413.4	7071	3860	1055	1730	426	
2009	6568.7	7245	3926	1055	1730	534	
2010	6739.0	7436	4651	1055	1730	0	1735
2011	6936.5	7657	4872	1055	1730	0	1459
2012	7254.1	8012	5227	1055	1730	0	1073
2013	7790.2	8613	5827	1055	1730	0	466
2014	8431.3	9331	6546	1055	1730	0	1281
2015	8871.2	9824	7039	1055	1730	0	754
2016	9118.8	10101	7310	1055	1730	0	411
2017	9351.9	10362	7577	1055	1730	0	86
2018	9592.9	10632	7847	1055	1730	0	2815
2019	10091.2	11190	8405	1055	1730	0	2226
2020	10647.4	11813	9028	1055	1730	0	1582

Table 9.9 Scenario C Business As Usual-Extended Import

Energy Balance[GWh] <u>Moderate Growth</u>

Year	Energy Forecast	Total Sent out	Supply				Export
			Kudu	Ruacana	Epupa	Import	
1999	2061.5	2196	0	1055		1141	
2000	2495.8	2683	0	1055		1628	
2001	2716.5	2930	0	1055		1875	
2002	2804.4	3029	1002	1055		972	
2003	2894.0	3129	2074	1055		0	
2004	2984.7	3231	2176	1055		0	
2005	3092.5	3352	2297	1055		0	
2006	3409.7	3707	2652	1055		0	
2007	3714.2	4048	2993	1055		0	
2008	3814.7	4160	3090	1055		15	
2009	3919.4	4278	3133	1055		90	
2010	4033.6	4406	3181	1055		170	
2011	4168.1	4556	3231	1055		270	
2012	4260.7	4682	3287	1055		340	
2013	4396.3	4812	3337	1055	1730	420	
2014	4515.2	4945	3390	1055	1730	500	
2015	4643.0	5086	3443	1055	1730	590	
2016	4763.1	5245	3510	1055	1730	680	
2017	4903.6	5379	3564	1055	1730	760	
2018	5025.8	5517	3612	1055	1730	850	
2019	5153.1	5659	3664	1055	1730	940	
2020	5283.3	5805	3720	1055	1730	1030	

Energy Balance[GWh] High Growth

Year	Energy Forecast	Energy Sent Out	Supply				Export
			Kudu	Ruacana	Epupa	Import	
1999	2099.3	2239	0	1055		1184	
2000	3469.3	3773	0	1055		2718	
2001	4407.2	4824	0	1055		3769	
2002	4733.4	5189	2291	1055		1843	
2003	4650.7	5321	3866	1055		400	
2004	4973.4	5458	3923	1055		480	
2005	5227.0	5742	4047	1055		640	
2006	5697.0	6269	4304	1055		910	
2007	6154.8	6781	4556	1055		1170	
2008	6413.4	7071	4686	1055		1330	
2009	6568.7	7245	4760	1055		1430	
2010	6739.0	7436	4831	1055		1550	
2011	6936.5	7657	4912	1055		1690	
2012	7254.1	8012	5082	1055		1875	
2013	7790.2	8613	5388	1055		2170	
2014	8431.3	9331	5756	1055		2520	
2015	8871.2	9824	5913	1055		2856	
2016	9118.8	10101	5913	1055		3133	
2017	9351.9	10362	5913	1055		3394	
2018	9592.2	10632	5913	1055		3664	
2019	10091.2	11190	5913	1055		4222	
2020	10647.4	11813	5913	1055		4845	

Table 9.10 Scenario D Business As Usual-CCGT

Energy Balance[GWh] Moderate Growth

Year	Energy Forecast	Total Sent out	Supply				Export
			Kudu	Ruacana	Epupa	Import	
1999	2061.5	2196	0	1055		1141	
2000	2495.8	2683	0	1055		1628	
2001	2716.5	2930	0	1055		1875	
2002	2804.4	3029	1002	1055		972	
2003	2894.0	3129	2074	1055		0	
2004	2984.7	3231	2176	1055		0	
2005	3092.5	3352	2297	1055		0	
2006	3409.7	3707	2652	1055		0	
2007	3714.2	4048	2993	1055		0	
2008	3814.7	4160	3090	1055		15	
2009	3919.4	4278	3133	1055		90	
2010	4033.6	4406	3181	1055		170	
2011	4168.1	4556	3231	1055		270	
2012	4280.7	4682	3287	1055		340	
2013	4396.3	4812	3757	1055		0	3745
2014	4515.2	4945	3890	1055		0	3574
2015	4643.0	5088	4033	1055		0	3396
2016	4783.1	5245	4190	1055		0	3200
2017	4903.6	5379	4324	1055		0	3034
2018	5025.8	5517	4462	1055		0	2863
2019	5153.1	5659	4604	1055		0	2685
2020	5283.3	5805	4750	1055		0	2501

Energy Balance[GWh] High Growth

Year	Energy Forecast	Energy Sent Out	Supply				Export
			Kudu	Ruacana	Epupa	Import	
1999	2099.3	2239	0	1055		1184	
2000	3469.3	3773	0	1055		2718	
2001	4407.2	4824	0	1055		3769	
2002	4733.4	5189	2291	1055		1843	
2003	4850.7	5321	3866	1055		400	
2004	4973.4	5458	3923	1055		480	
2005	5227.0	5742	4047	1055		640	
2006	5697.0	6269	4304	1055		910	
2007	6154.8	6781	4556	1055		1170	
2008	6413.4	7071	4686	1055		1330	
2009	6568.7	7245	4760	1055		1430	
2010	6739.0	7436	4831	1055		1550	
2011	6936.5	7657	4912	1055		1690	
2012	7254.1	8012	5082	1055		1875	
2013	7790.2	8613	7399	1055		159	
2014	8431.3	9331	8003	1055		273	
2015	8849.3	9799	8253	1055		516	
2016	9118.8	10101	8374	1055		672	
2017	9351.9	10362	8491	1055		816	
2018	9592.9	10632	8611	1055		966	
2019	10091.2	11190	8893	1055		1242	
2020	10647.4	11813	9201	1055		1557	

Energy Balance[GWh] **Low Growth**

Year	Energy Forecast	Energy Sent Out	Peak Load (MW)	Supply				Export (Desirable)
				Kudu	Ruacana	Epupa	Import	
1999	2013.0	2149	383		1055			
2000	2119.4	2262	407		1055			
2001	2201.9	2354	426		1055			
2002	2267.2	2427	441		1055			
2003	2329.7	2497	456	1442	1055		0	-
2004	2391.1	2566	470	1511	1055		0	-
2005	2453.0	2635	485	1580	1055		0	-
2006	2511.4	2700	499	1645	1055		0	-
2007	2568.1	2764	513	1709	1055		0	-
2008	2614.6	2816	524	1761	1055		0	1385
2009	2668.4	2876	538	1821	1055		0	1300
2010	2723.6	2938	552	1883	1055		0	1213
2011	2792.0	3015	568	1960	1055		0	1116
2012	2842.9	2742	581	1687	1055		0	1036
2013	2892.1	3127	593	2072	1055		0	5149
2014	2947.7	3189	607	2134	1055		0	5149
2015	2999.8	3248	619	2193	1055		0	5149
2016	3051.5	3306	632	2251	1055		0	5149
2017	3101.5	3362	644	2307	1055		0	5149
2018	3151.8	3418	656	2363	1055		0	5149
2019	3203.4	3476	668	2421	1055		0	5100
2020	3255.3	3534	681	2479	1055		0	5020

Total sent out = Energy forecast - 100GWh(non-interconnected supplies)
+ 12%(transmission losses)

Table 9.11 Scenario E. Business As Usual-Hydro

Energy Balance[GWh] Moderate Growth

Year	Energy Forecast	Total Sent out	Supply				Export
			Kudu	Ruacana	Epupa	Import	
1999	2061.5	2196	0	1055		1141	
2000	2495.8	2683	0	1055		1628	
2001	2716.5	2930	0	1055		1875	
2002	2804.4	3029	1002	1055		972	
2003	2894.0	3129	2074	1055		0	
2004	2984.7	3231	2176	1055		0	
2005	3092.5	3352	2297	1055		0	
2006	3409.7	3707	2652	1055		0	
2007	3714.2	4048	2993	1055		0	
2008	3814.7	4160	3090	1055		15	
2009	3919.4	4278	3133	1055		90	
2010	4033.6	4406	3181	1055		170	
2011	4168.1	4556	3231	1055		270	
2012	4280.7	4682	3287	1055		340	
2013	4396.3	4812	2027	1055	1730	0	987
2014	4515.2	4945	2200	1055	1730	0	815
2015	4643.0	5088	2303	1055	1730	0	638
2016	4783.1	5245	2460	1055	1730	0	441
2017	4903.6	5379	2594	1055	1730	0	3341
2018	5025.8	5517	2732	1055	1730	0	3782
2019	5153.1	5659	2874	1055	1730	0	2991
2020	5283.3	5805	3020	1055	1730	0	2808

Energy Balance[GWh] High Growth

Year	Energy Forecast	Energy Sent Out	Supply				Export
			Kudu	Ruacana	Epupa	Import	
1999	2099.3	2239	0	1055		1184	
2000	3469.3	3773	0	1055		2718	
2001	4407.2	4824	0	1055		3769	
2002	4733.4	5189	2291	1055		1843	
2003	4850.7	5321	3866	1055		400	
2004	4973.4	5458	3923	1055		480	
2005	5227.0	5742	4047	1055		640	
2006	5697.0	6269	4304	1055		910	
2007	6154.8	6781	4556	1055		1170	
2008	6413.4	7071	4686	1055		1330	
2009	6568.7	7245	4760	1055		1430	
2010	6739.0	7436	4831	1055		1550	
2011	6936.5	7657	4912	1055		1690	
2012	7254.1	8012	5082	1055		1875	
2013	7790.2	8613	4826	1055	1730	1272	
2014	8431.3	9331	4923	1055	1730	1623	
2015	8871.2	9824	5173	1055	1730	1811	
2016	9118.8	10101	5094	1055	1730	2049	
2017	9351.9	10362	6911	1055	1730	708	
2018	9592.2	10632	7031	1055	1730	873	
2019	10091.2	11190	7313	1055	1730	1161	
2020	10647.4	11813	7621	1055	1730	1476	

9.5 Short Term Expansion Options

The decision was taken by NamPower to construct a new 400kV interconnector with Eskom and the contracts for the construction were awarded in November 1997. Furthermore a generation addition will be urgently reqired in the year 2002 in order to meet a sharply growing demand.

NamPower has reached agreement in principle with Eskom and Shell to build a Kudu gas fired combined cycle power plant. Keeping in mind the energy self sufficiency in the future, construction of the second 400kV line should be avoided. A hydropower plant requires a long lead time. Under the above mentioned circumstances the short term expansion option shall be one alternative common to all scenarios.

9.6 Medium and Long Term Expansion Options

Regarding a hydropower project, the year 2008 in Scenario B would be the earliest possible time for its completion and the year 2013 in Scenario E be the completion time required by the system demand. It would be too heavy and risky for the national economy to build two large hydropower schemes in overlap. Shortage of a hydropower is planned to be supplemented by CCGT or its free cycle gas turbines.

Self Sufficiency Scenarios A and B require a block of CCGT in addition to corresponding Business As Usual Scenarios D and E. A self sufficiency scenario would cost additional US$406 million compared with a corresponding business as usual scenario in the time horizon until 2020. On the other hand the degree of self sufficiency of Scenario D would reach from 22% in 2001 to 79% in 2010 and 87% in 2020.