Chapter 9:
EVALUATION OF ALTERNATIVE ENERGY SOURCES

9.1. FOCUS AND SCOPE OF EVALUATION

Least-cost system expansion planning constitutes the core of designing investment programmes in the power sector, where the objective is to minimise the cost of meeting the additional demand for power and energy, subject to an acceptable level of reliability. The alternative sources of supply that are compared in this context are conventional sources of energy based on well-proven technologies that are relevant in the Namibian energy market. Different generation scenarios that meet the demand forecasts, with and without the proposed hydropower development, are compared on the basis of costs. The simulations carried out to determine the least-cost expansion plan for Namibia and to ascertain whether or not the development of Epupa is part of such a plan, are main elements of the system study and the economic analysis of the proposed hydropower scheme.

The same analysis constitutes a suitable starting point for the evaluation of energy alternatives to hydropower, insofar as additional sources of energy to the conventional ones may be evaluated within the same framework. For the alternative energy evaluation, the framework has been expanded in two directions: (i) the alternatives that have been added for the purpose of the simulations also include solar energy, windpower and conservation; and (ii) in addition to a presentation of costs associated with each supply alternative, a comparison of the alternatives is made on the basis of certain other criteria.

In line with the premise that the hydropower project, if developed, will be connected to the national grid, the present analysis focuses on the application of electricity alternatives that are relevant for grid connection. Thus, applications of energy alternatives that are relevant primarily for supply to isolated centres or to rural areas fall outside the scope of the present evaluation and are addressed only summarily.

9.2. APPROACH

Demand for additional energy in Namibia in the future will have to be met by a combination of supply alternatives. The supply alternatives have been combined into different supply scenarios, or packages, all capable of meeting projected demand up to 2020 and subject to satisfying certain minimum technical requirements. Hence, the scope for and role of the individual energy alternatives are assessed in combination with other options, rather than individually. This procedure, the system approach, helps ensure that the options are assessed in terms of their role and contribution to the overall system output, as well as in terms of their impact on system costs.

The system approach, also known as the least cost system analysis, is in line with one of the major objectives of any government, and in particular a government in a developing country, which is to increase national income. Least cost solutions are a necessary condition for maximising national income. Therefore, the minimisation of costs is taken as the single most important criterion for evaluating the different power supply options and combinations in the alternative energy evaluation.
There are, however, other dimensions along which it is important to evaluate the supply alternatives, and which cannot be incorporated in a monetized criterion such as cost minimization. These correspond to objectives to which a government may be committed, other than that of increasing national income.

The following criteria are considered relevant for evaluation of alternative supply scenarios:

- Present value of power system costs
- Reliability of supply
- Self-sufficiency (independence of supply)
- Risk
- Environmental factors (not already accounted for in the cost estimates)
- Technology and timing
- Financing

Whereas costs are expressed in monetary terms, most of the other criteria do not lend themselves to monetary valuation. Some of them may be quantified (stopping short of valuation), whereas others may only be expressed in qualitative terms. In either case, a comparison of the supply options based on a uniform yardstick for all the different dimensions is impossible. Without a uniform yardstick, two issues are raised: (i) the question of the relative importance (weight) of a non-monetized factor compared to the other criteria; and (ii) how to indicate the relative importance of the impact of a particular supply option with respect to the criterion under consideration. Assigning numbers to indicate weights and relative impacts is an arbitrary exercise and is refrained from here.

In the end, therefore, the comparison of the supply scenarios will be based partly on cost figures and partly on qualitative statements with respect to the non-monetized evaluation criteria related to each option. The consultant can point to the consequences of the supply scenarios along different dimensions. The final weighing of costs together with the other (non-monetized) factors, and hence the choice of future generation expansion plan, however, is the realm of the country’s authorities.

9.3.  POWER SUPPLY OPTIONS

9.3.1    Overview

Electricity supply of Namibia comes from imports from RSA and from domestic generation of which the main contributors are the coal-fired Van Eck Power Station (120 MW) just outside Windhoek, the hydroelectric plant at the Ruacana Falls in the north (maximum capacity 240 MW), and the diesel-driven Paratus Power Station located at Walvis Bay (24 MW). Over the fiscal years 1994 - 1996, imports from RSA accounted for from 38% to 55% of total supply in Namibia, the balance coming from domestic sources.

The only large scale hydropower resource is the Cunene River which draws its waters from the mountains of central Angola. Over the rest of the country, the low rainfall means that the majority of the rivers are seasonal and cannot be economically harnessed for electric power production. The Cunene River constitutes, however, one of the main
energy resources of Namibia, with the sites in the vicinity of the Epupa Falls or at Baynes having been identified as the most promising ones.

The evidence to hand suggests that the offshore Kudu Gas Field is a world-scale gas field which could well become an alternative energy source for the country in the future. The field is under investigation by Shell and is believed to contain at least sufficient gas to run a 1,000 MW combined cycle gas plant for 50 years.

Wind power is well established and is the main source of energy for water pumping in the commercial farm area. Apart from the use of a small number of wind chargers for batteries, however, wind power is at present not used for electricity generation. The coastal areas have high and relatively constant wind speeds, and wind measurements are being performed to assess the potential for electricity generation on a scale suitable for grid connection.

Namibia has around 3,300 hours of sunshine per year which is one of the highest national figures in the world. There are, however, considerable seasonal variations in the south. Detailed figures are not available for the north and north-east but insolation levels, because of the greater number of cloudy days, are less than in the more southerly areas. A number of photovoltaic systems have been installed to supply isolated areas with small quantities of energy, and solar irradiation monitoring is at present being carried out, primarily in the south.

9.3.2 Imports

Imports of electricity from RSA to NAMPOWER is over two parallel 220 kV circuits with a maximum capacity of about 225 MW. The southern area of Oranjemund is supplied directly from the ESKOM system in RSA.

The construction of a new 400 kV interconnector from the Aries sub-station in RSA through Kokerboom to a new substation, Auas just outside Windhoek is under implementation. The new line is expected to be in operation from 1999 with a transfer capability of about 540 MW. If reinforced, the new interconnector will increase the total transfer capacity between NAMPOWER and ESKOM in South Africa to around 900 MW.

With the new line, the total supply capacity from imports and existing domestic power stations will be sufficient to meet projected electricity demand in Namibia for the next 1-2 decades.

However, if such a scenario develops Namibia would be highly import dependent and exposed to developments in South Africa. Because of the tightening supply-demand balance in RSA, where excess capacity is expected to be digested around 2005, Namibia would then most probably have to pay the price of additional capacity in RSA.

In the present study, a two tier tariff for peak and off-peak energy has been used, with USc 7/kWh in the peak period and an off-peak tariff of USc 2/kWh, both in fixed 1997 prices and valid from 2005.

9.3.3 Combined Cycle Generation based on Kudu Gas
Shell has opted for a stepwise development of the Kudu field. The first step is to develop the Kudu field primarily for generation of electricity in Namibia. The next step is to develop a larger export scheme concurrent with the need for additional energy in Southern Africa.

To this end, Shell's idea (January 1997) was to study a possible combined cycle installations at Oranjemund ranging from 300 MW to 1,300 MW. Shell has later agreed to study the project together with ESKOM of RSA and NAMPOWER.

The consultant has made his own assumptions in order to assess the feasibility of electricity generation based on Kudu gas. The assessment is based on assumptions made for the cost of natural gas as feedstock to the Combined cycle (CC) plant, the cost of CC generation and the cost of a transmission line from Oranjemund to the nearest connection point of the national grid assumed to be Kokerboom.

The cost of Kudu gas landed at Oranjemund and treated for use in a CC power station has been set at USD 2.0/GJ (or 1.3 USc/kWh) in the study of alternative supply options. The gas price used was initially quoted by Shell as a reference price for Kudu gas delivered Oranjemund. In subsequent discussions, SCFS and the consultant have agreed to use this price as the reference price for natural gas input to the power station in the least cost system expansion simulations.

Based on an independent calculation of gas cost made by the Consultant, the assumption of USD 2.0/GJ applied in the study of alternatives appears much too low. A minimum development concept of the Kudu field with sufficient capacity to fuel a 360 MW combined cycle power plant at Oranjemund would need a gas price of 4.5 USD/GJ (or 3 USc/kWh) to yield a real rate of return of 10 percent on capital invested. In the economic comparison between Epupa and the Kudu alternative this gas price has been assumed.

For the CC power plant, state of the art technology and prices have been assumed for investments and operation. The assumptions applied are:

Investment cost 680 USD/kW
Fixed O&M cost 10 USD/kW
Variable O&M cost 0.6 USc/kWh
Heat rate (efficiency) 6 140 BTU/kWh (0.55)

All prices are fixed 1997 prices.

The cost of power transmission from the CC plant at Oranjemund to the nearest connection point in the main grid of NAMPOWER has been estimated at 0.25 - 0.50 USc/kWh dependent on the volumes of power transported. The cost estimates assume a 400 kV double circuit line.

Based on the assumptions presented above, the unit cost of electricity from Kudu gas for alternative generation capacities and comparable with Epupa/Baynes supplies at the nearest high voltage connection point of the Namibian grid can be summarised as follows:
Unit cost of electricity based on Kudu gas (USc/kWh)

<table>
<thead>
<tr>
<th>Installed capacity</th>
<th>360 MW</th>
<th>750 MW</th>
<th>1300 MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas cost</td>
<td>3.0</td>
<td>1.4</td>
<td>0.8</td>
</tr>
<tr>
<td>CC generation cost*</td>
<td>1.8</td>
<td>1.8</td>
<td>1.8</td>
</tr>
<tr>
<td>Transmission cost</td>
<td>0.5</td>
<td>0.35</td>
<td>0.25</td>
</tr>
<tr>
<td>Total</td>
<td>5.3</td>
<td>3.55</td>
<td>2.85</td>
</tr>
</tbody>
</table>

* Variable O&M (0.6 USc/kWh) + Fixed cost (1.2 USc/kWh) at 80 percent capacity utilisation of CC plant, step-wise fixed average generation costs in 300-400 MW trains and economic lifetime 25 years.

9.3.4 Coal Fired Steam Units

For the thermal electricity production option based on coal a conventional greenfield steam technology, the following cost characteristics have been assumed in the alternatives study:

- Investment cost: 1,200 USD/kW
- Fixed O&M cost: 23 USD/kW
- Variable O&M cost: 0.5 USc/kWh
- Coal consumption: 0.4 Kg/kWh
- Fuel cost: 50.0 USD/ton, 2.0 USc/kWh

The thermal option based on coal proves to be far more expensive than other conventional options such as hydropower from the Cunene and CC generation from Kudu gas. The investment cost is approximately the double of today’s CC cost per kW of installed capacity and the fuel cost is high due to expensive transportation from the closest coal deposits.

9.3.5 Solar Energy

General

Namibia is extremely well endowed with solar energy. Over the whole country, the annual average irradiation on a horizontal surface is estimated to be about 2,200 kWh/m²; this increases to around 2,500 kWh/m² if the surface is tilted to about 36° to maximise the amount of radiation it receives. The exact figure for the annual irradiation will, however, vary depending on the location and the locally prevailing meteorological conditions and may be considerably less in some areas. A working figure of 2,250 kWh/m², irrespective of location, is assumed for the analysis presented here.

Electricity can be generated from solar energy by using the heat of the sun to raise steam which is used to drive a conventional steam turbine. This is normally referred to as solar thermal generation of electricity and is mainly seen as a means of producing electricity to be fed directly into the power grid.
Alternatively, photovoltaic (PV) cells can be used to transform solar radiation directly into electricity. The technology is mature and fully commercial in a wide range of uses including the provision of electric power for telecommunications, signalling, cathodic protection and other remote high-value uses. Small stand-alone PV systems for individual households are beginning to break into the mass commercial market in a number of developing countries.

Interest in the use of PVs to provide electricity directly to the grid has also been growing in recent years. A substantial amount of research and demonstration work on grid-connected PV power generation has already been carried out in Europe, the US and elsewhere and a number of demonstration projects have been implemented.

Solar energy can also be used directly, without being transformed into electricity, for water heating. In Namibia, where electric water heaters are widely used in urban households, the widespread use of solar water heaters would tend to bring a reduction in the demand for electricity.

The environmental impact of electricity generation using solar thermal or PV power stations is relatively minor and much less than using conventional fossil fuel stations. The land requirements are large but this is hardly a problem in Namibia where the best sites from the point of view of the solar irradiation are in uninhabited desert or near-desert areas. There are no carbon dioxide or other emissions as a result of the conversion of solar energy to electricity.

Construction requirements for solar thermal plants are broadly similar to those of conventional plants, though specialised expertise is required for the construction and maintenance of the mirror system. Depending on the design, there may be a substantial requirement for cooling water but this can be met by siting the station near the sea. Construction requirements for PV systems are minor.

**Solar Thermal Power Stations**

Experimental and small scale demonstration work has been carried out on a variety of technical approaches to solar thermal electricity generation but two, the solar tower and the parabolic trough, stand out as the most promising. The solar tower technology is, however, still at a demonstration stage and the largest installation built to date has a maximum electricity output of 10 MW.

The main commercial development of the parabolic trough technology has been carried out by the Luz Company of Israel. Nine solar plants with a total installed peak generating capacity of 354 MWe were built during the 1980s in the Mojave Desert in southern California. The area of mirrors involved was huge; those for the 80 MW plants cover a total of 46 hectares.

The first plant started operation in 1985. Although there were, inevitably, some technical teething problems, the plants have performed satisfactorily. The annual efficiency of conversion of solar energy to electricity is in the range 10-14%.

The Luz Company has, however, experienced increasing commercial problems. It eventually had to file for bankruptcy and was liquidated at the end of 1991. The power stations, which are owned by private investor groups, nevertheless, continue to operate.
For the purpose of the present analysis, it is assumed that a 160 MW gas-solar thermal power station is built. Although this is twice the size of the largest such station built to date, it still poses a practical difficulty for the analysis since the cost of a 160 MW off-take from the Kudu gas field only could not be justified economically. It is therefore assumed that the Kudu off-take corresponds to gas for a 360 MW plant of which gas for the needs of 200 MW power is sent by pipeline to South Africa. This gives a landed natural gas price of around USD 5.0/GJ.

The assumed 160 MW gas-solar thermal power represents the latest thinking about such stations and should provide certain economies of scale over the 80 MW Californian plants. A cost of 2,900 USD/kW, excluding IDC, is taken as a working estimate for the present analysis. It is assumed that the plant works for a total of 7,000 hours per year.

The gas used in a gas-solar plant could, of course, be used for a 160 MW gas-only power station. The difference in costs between the gas-only and the gas-solar plants represents the additional cost of the solar component and can be used as a basis for calculating the marginal cost of the solar-generated electricity. In practice, the solar-only component would not be built on its own, but breaking the analysis down in this way provides an opportunity to assess the real cost of the solar-generated electricity in the most transparent way.

The detailed cost data for the three options are given below:

**160 MW combined-cycle gas plant**

- Total investment: USD 109 million
- Capital cost/kW: USD 680
- Plant working life: 20 years
- Discount rate: 10%
- Operating time/yr: 7,000 hours
- Plant efficiency: 55%
- Investment cost/kWh: USc 1.1/kWh
- O&M cost: USc 0.6/kWh
- Natural gas cost: USD 5.0/GJ
- Total generating cost: USc 5.0/kWh

**160 MW gas-solar thermal plant**

- Total investment: 464 million
- Capital cost/kW: USD 2,900
- Plant working life: 20 years
- Discount rate: 10%
- Operating time/year: 7,000 hours (2,250 hrs solar and 4,750 hrs gas)
- Fuel cost:
  - gas-fired: USc 3.3/kWh
  - solar: 0
  - average: USc 2.2/kWh
- Investment cost/kWh: USc 4.9/kWh
<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>O&amp;M cost</td>
<td>USc $1.0/kWh</td>
</tr>
<tr>
<td>Total cost</td>
<td>USc $8.1/kWh</td>
</tr>
</tbody>
</table>
160 MW solar component

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total additional investment</td>
<td>USD 355 million</td>
</tr>
<tr>
<td>Cost/kW</td>
<td>USD 2,218/kW</td>
</tr>
<tr>
<td>Plant working life</td>
<td>20 years</td>
</tr>
<tr>
<td>Discount rate</td>
<td>10%</td>
</tr>
<tr>
<td>Operating time per year</td>
<td>2,250 hours</td>
</tr>
<tr>
<td>Fuel cost</td>
<td>0</td>
</tr>
<tr>
<td>Investment cost/kWh</td>
<td>USc 11.6/kWh</td>
</tr>
<tr>
<td>O&amp;M cost</td>
<td>USc 1.7/kWh</td>
</tr>
<tr>
<td>Marginal cost of solar gen.</td>
<td>USc 13.3/kWh</td>
</tr>
</tbody>
</table>

The above calculations show that the cost of generating electricity in a 160 MW combined cycle gas turbine using natural gas at USD 5.0/GJ is USc 5.0/kWh. When a solar-thermal component is added to this station, and used to its maximum, the average cost of the electricity produced jumps 60% to USc 8.1/kWh. The reason is that the marginal cost of the electricity from the solar component is USc 13.3/kWh.

Reductions in the costs of the solar components of gas-solar power stations can be expected if ordering in significant numbers begins to take place in the international market. It is impossible to put any firm time scale on this as, at present, no such orders have been placed. Taking an optimistic view, it might be assumed that orders will have built up to a level at which prices have fallen by 40% by the year 2010. This would still leave a generation cost of around USc 8.0/kWh for the solar component.

In the light of this analysis, there does not appear to be any realistic prospect of solar thermal electricity generation becoming competitive in Namibia over the next ten to fifteen years and it can therefore be excluded as a large-scale option for the immediate future.

Grid Connected Solar Photovoltaic (PV) Power Plants

The price of PV cells has been steadily falling over the past three decades. At the same time, their efficiency and reliability have been rising. The PV cells are incorporated into modules which are the basic components in all PV systems.

Based on recent figures for other countries, the present delivered cost of a large order of modules, CIF Namibia, is likely to be about USD 5.0/Wp. Adding the cost of arrays, supports, fencing, foundations, current-conversion equipment, wiring, control and protection systems, as well as labour and transport, the overall cost for a grid connected system in Namibia can be taken as USD 7/Wp or USD 7,000/kWp.

In calculating the unit cost of the electricity produced, the average annual output per installed kWp is taken as 2,250 kWh and the lifetime of the system as 20 years. With a discount rate of 10%, and an O&M cost of 5%, the electricity cost is USc 38/kWh. At this level, grid-connected PV is clearly of no practical interest in Namibia at present.

It is widely anticipated, and borne out by the historical record, that module prices will continue to fall. The ancillary costs for supports, wiring and other components, as well as transport and labour, are, however, unlikely to fall at the same rate. Assuming a module cost of USD 2.5/Wp and USD 1.5/Wp for other components and construction, gives an
installed cost of USD 4.0/Wp. With the same lifetime, discount rate and O&M allowance, this gives a cost of USc 22/kWh for the electricity produced.

This is still far in excess of the cost of electricity generation from conventional sources and, indeed, of solar thermal power stations. No large scale use of grid-connected PV systems can therefore be anticipated in Namibia within the next two decades. This does not, however, preclude the possibility of some limited specialist, rather than bulk supply grid-connected uses, within the same time-frame.

**Summary Conclusions on Grid-Connected Solar Power in Namibia**

The use of solar energy to generate electricity for direct supply to the grid is technically proven. It is environmentally benign and produces neither noxious by-products or greenhouse gases.

There has now been a significant amount of practical experience in the operation of solar thermal power stations. Despite this, they remain economically unattractive in the Namibian context. Present marginal costs of solar generation appear to be about USc 13.0/kWh compared with USc 3-5 kWh for combined cycle gas plants depending on the assumed volume of the gas off-take from the Kudu field.

Prospects that solar thermal generation technology will become economically attractive for Namibia within the next 10-15 years are poor. Thereafter, depending on the whether an international market for the technology develops and the level of fossil fuel prices rises appreciably, the prospects for solar thermal electricity generation may begin to improve.

Despite the relatively poor economic outlook for solar thermal generation over the next 10-15 years, Namibia may feel that a certain limited investment is justified to obtain a foothold in the technology and build up technical skills. This could be achieved, for example, by a donor-sponsored pilot project in the 1-10 MW range. This option should, however, be weighed against other, possibly more precisely and practically targeted, investments of the same finance and manpower in developing more immediately relevant national technical capabilities.

Prospects for a significant contribution from grid-connected PV are poorer than those of solar thermal technology. At present, generation costs are around USc 38/kWh. Even with a projected halving of module costs within the next 10-15 years, this will still leave total generation costs at around USc 22/kWh which is not relevant for bulk power generation.

**9.3.6 Wind Energy**

**General**

Average wind speeds vary widely over the country. In the commercial farm areas, wind speeds are too low for power generation but the wind regime is suitable for the use of multiblade windmills which have long been used for water pumping. Wind speeds are lower still towards the north of the country and there are long periods of calm, making wind utilisation either for electricity generation or water pumping generally impracticable.
Along the coast, wind speeds are considerably higher but few detailed long term records are available. The only reliable information presently available is from a study carried out by the Ministry of Mines and Energy, with support from Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), at the coastal sites of Walvis Bay and Luderitz. The final report of this study was presented to the Ministry in April 1997 and is included in Appendix 5.1 (Part B4, Vol. 1).

Under this study, wind measurement devices were installed at Walvis Bay and Luderitz in October 1995 and December 1995 respectively. These devices were replaced by more sophisticated data loggers in July 1996. In both cases, the wind data was collected from a 10 metre high mast. The mast at Luderitz was located on the edge of a cliff which introduces a significant degree of uncertainty into the representativeness of the readings.

Wind speed measurements are notoriously site specific, even small differences in topography can have major effects. This is especially true when measurements are taken at the 10 metre height unless great care and expertise has been used in the choice of measurement site to avoid errors or distortions. The reason such care is needed is that the output of power generating wind turbines is extremely sensitive to the wind speed; halving the wind speed reduces the output by a factor of eight. Hence, a more comprehensive data collection programme has been commissioned.

The existing data in Walvis Bay shows that the prospects for low-cost electricity generation in the area are poor. The Ministry report says that the mean windspeeds “were at the low end of what could be considered useful for economic power generation”. The available records show that the proportion of the total time at which there is no output from a standard wind turbine was 48% and a further 12% was at 5%. The estimated capacity factor was 17%.

The existing data from Luderitz are better. The Ministry report states that the windspeeds “were sufficient to sustain significant wind electric generation”. The proportion of the time showing zero output is, however, 41% with a 8% of the time at 5% of output. The estimated capacity factor was 36%.

Wind power has been used for water pumping for over a thousand years and has a long and successful history in Namibia. The multiblade windmills in widespread use in the commercial farm areas have provided many decades of reliable and cost-effective power for pumping water from considerable depths -often in excess of 100 metres. Coverage in the commercial farm areas is already more or less complete and over 30,000 of these machines are estimated to be in use. The potential for extending their use into northern Namibia is, however, limited because of the lower wind speeds and longer periods of calm in the area.

Wind turbines installed in the early 1980s tended to have rated outputs in the range 50-250 kW. Many of these were installed, for example, in California where they are now reaching the end of their working life. Since then, sizes have increased considerably and are now generally in the range 400-800 kW. Development work is continuing on machines with capacities up to 1.5 MW. Capacities significantly above this are unlikely in the immediate future for a variety of technical reasons.

Although the output from wind turbines tends to vary considerably, 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, a considerably higher figure than yet reached anywhere to date.

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. This reduces the generating capacity “credit” which can be allowed for wind power installations. The available data in Namibia suggest that wind energy installations would allow no capacity reduction and would simply save fuel, or water, at existing power stations.

Costs

Wind turbine costs are now much lower than in the early 1980s. In the UK, the installed cost in 1996 was reported to be USD 1,050/kW. In Germany it was USD 1,370/kW and in Sweden it was USD 1,150/kW. The European Commission states that the “turnkey cost of a typical wind installation is of the order of 1,000 ECU/kW” - equivalent to USD 1,130/kW. A working figure of USD 1,200/kW, which allows for some additional transport and logistic costs, is assumed here for Namibia.

It is conventional to express the annual output of wind turbines in terms of the load factor. This is the equivalent proportion of the year with the machine operating at its rated capacity. The Luderitz data suggest a possible load factor of 0.36 while Walvis Bay suggests 0.17 but further data are required before a truly representative value can be calculated. Internationally, a load factor of 0.25, which represents about 2,200 hours operating at its rated capacity, is generally considered as a satisfactory performance and is adopted here.

The following figures are taken for a hypothetical installation in Namibia:

- Capital cost/kW installed: USD 1,200/kW
- System life: 20 years
- Discount rate: 10%
- Load factor: 0.25
- Output/year: 2,200 kWh
- Investment cost/kWh: USc 6.4
- O&M cost, 10%: USc 0.6
- Total cost/kWh: USc 7.0

The above calculated cost of USc 7.0/kWh is in line with present generally known figures for electricity generation from wind energy. The European Commission report referred to above quotes a figure of ECU 0.06/kWh (USc 6.8/kWh) depending on the site. At around USc 7.0, the cost of electricity from wind power is significantly higher than the total cost of electricity from conventional sources and very much higher than the cost of the fuel which would be saved. Under present conditions, it is therefore not an attractive option for the country.
Given the already advanced state of the technology, as well as the fact that much of the structure of a wind turbine, such as the support tower, is relatively conventional structural engineering, the prospects of radical technological breakthroughs or major cost reductions are relatively limited in the immediate future. Assuming a cost reduction of 30% over the next 10-15 years, the generation cost would fall to USc 4.9/kWh which is still higher than any likely fuel savings and therefore not economically attractive for NAMPOWER or the country.

These conclusions represent an optimistic interpretation of the existing data. It is possible that the programme of further wind energy measurements being planned by the Ministry of Mines and Energy will show the wind energy potential to be more favourable than presently appears to be the case. It is, however, highly unlikely that wind power will be competitive in Namibia in the near to medium future because of the low price of the available alternatives.

### 9.3.7 Summary - Wind and Solar Generation

The following table summarises the results for the grid-connected options of wind, and solar thermal electricity generation. These are compared with the reference costs for conventional generation based upon existing costs to NAMPOWER of imports from South Africa and the estimated LRMC of generation. Because the exact optimal locations for wind and solar installations are not known, the bus-bar costs are given in all cases.

The present costs per kWh are calculated on the basis of known or estimated costs for current or near future projects. The 2010 estimates are based on current projections of cost reductions.

<table>
<thead>
<tr>
<th>Option</th>
<th>Present cost (USc/kWh)</th>
<th>Projected cost in 2010 (USc/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional(1)</td>
<td>1.8(1)</td>
<td>3.0</td>
</tr>
<tr>
<td>Solar thermal(2)</td>
<td>13.3</td>
<td>10.0</td>
</tr>
<tr>
<td>Grid connected PV</td>
<td>38.0</td>
<td>22.0</td>
</tr>
<tr>
<td>Wind</td>
<td>7.0</td>
<td>4.9</td>
</tr>
</tbody>
</table>

1) Present cost of imported electricity.
2) The estimated cost of the solar thermal component in a gas-solar power station

It can be seen that the grid-connected solar thermal, PV, and wind options are not economically justifiable at present or in the year 2010. It would therefore appear that no major role should be envisaged for these technologies in the Namibian generating system over the next twenty years.

This review is thus pessimistic about the near to medium term future for large scale renewables in Namibia. This is mainly because the available conventional energy resources are cheap by world standards and likely to remain so over, at least, the next 15-20 years. Large scale promotion of the use of renewables would consume economic resources which could otherwise be used for other investments.

In the longer term future, however, and especially if there is a major upward movement in oil prices, it is likely that solar and wind power will become more attractive. It is therefore important that the Namibian government maintains a foothold in these technologies. This can be achieved by ensuring that there is a build-up of relevant data, especially wind, and...
by limited investments in well-designed pilot projects - with as much donor assistance as possible. As these technologies become more competitive in terms of cost, the Government can investigate the possibilities of soft or grant financing from bilateral sources or from multilateral lending agencies such as the Global Environment Facility.

9.3.8 Energy Conservation

The short term potential for energy conservation is dependent on the energy use pattern at present. In the longer term perspective, the driving forces of economic growth have to be analysed in order to determine possible routes of minimising growth in energy, while at the same time making energy available at affordable prices in order to achieve the development objectives of society. The conflicting goals of economic growth and conservation of resources thus have to be balanced in order to reach sustainable development.

Electricity consumption of Namibia is dominated by use in households, small scale manufacturing, government and commercial services, the so called general supplies, with more than 50 percent of total electricity consumed of which 4/5 in three main urban centres. Mining accounts for 40 percent while rural supplies including pumping consumes 8.5 percent. Even though more than 70 percent of the population live in rural areas, rural supplies excluding electricity for water pumping amounted to only 4.5 percent of total electricity consumed in Namibia in 1994/95.

Per capita electricity consumption in Namibia is low by international comparison, only 1 250 kWh per year. When energy intensive industries such as mining, water pumping and manufacturing are excluded the per capita electricity consumption in rural areas of Namibia is particularly low, only 70 kWh in 1994/95.

Based on the demographic trends, population growth is set at 3.1 per cent per annum for the entire forecast period up to year 2025. The recent urbanisation trend is expected to continue, but at a slower pace as time passes. Activity in commercial services and small scale manufacturing, primarily with relatively low energy intensity, is expected to grow relatively fast (5 percent p.a. 2001 - 20025), while government activities are expected to expand by 1 percent p.a. 2001-2025. In mining, electricity consumption is primarily determined by the demand for mining outputs, which again is determined by the international mineral markets.

Based on above description of the structure and likely trend in the electricity consumption of Namibia, the potential for energy conservation beyond what has already been included in the electricity demand forecasts is limited.

First of all, the existing consumption of electricity is relatively low and therefore the potential for substantial reductions in the present use of electricity is limited. Only a small share of the population, primarily those living in the urban areas, has access to electricity. In consequence extension of the grid to the rural areas is a priority and might trigger an increase of electricity consumption rather than a decrease relative to the medium growth forecast, which assumes a modest growth in rural electricity consumption of 4 per cent p.a. from a low starting point.

Secondly, the projected growth in electricity demand is primarily a result of population growth and the growth in economic activity required to create more
employment and income opportunities, both for the present underemployed population and the newcomers to the workforce.

However, there is possibly a certain potential for more efficient use of electricity than reflected in the medium growth forecasts, notably in some of the high income urban households and in mining. The reason for this postulate is that the average sales price of electricity from NAMPOWER has dropped by 50 per cent in real terms since 1982 and is now very low by international standards (3.7 USc/kWh). This trend is reflected in the end user electricity tariffs. Accordingly, there has been little incentive for consumers to economise on the use of electricity. By increasing the electricity tariff, consumption could be disciplined leading to more efficient use of energy.
9.4. EVALUATION OF SCENARIOS

The table below shows results according to the criteria presented in Section 9.2. The Present Value of System Cost 1999-2050 (PV) is based on simulations of the power system as described in Chapter 5. The conclusions on the other criteria are based on qualitative statements. The final weighing of costs and the other (non-monetised) factors in order to arrive at a decision as to the preferable supply option must be made by the parties directly involved in the decision making process related to the proposed project.
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