AN INTEGRATED APPROACH TO ENERGY SUPPLY AND DEMAND: THE ROLE OF NUCLEAR ENERGY IN SOUTHERN AFRICA

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SUMMARY

The importance of an integrated approach to the development of an electricity strategy for Southern Africa is emphasized in view of the numerous options and initiatives that are available for supply and demand side management. Apart from present uncertainties concerning future electricity demand, other factors such as the availability of coal and uranium and the comparative costs of nuclear and coal-based electricity are regarded as the most important parameters which have as yet not been sufficiently quantified to decide on the timing and extent of nuclear energy in Southern Africa.

OPSOMMING

Die belangrikheid van 'n geïntegreerde benadering tot die ontwikkeling van 'n elektrisiteitstrategie vir Suidelike Afrika word beklemtoon in die lig van die verskeie moontlikhede en inisiatiewe veral ten opsigte van voorsiening en vraagkantbestuur. Benewens huidige onsekerhede oor die toekomstige vraag na elektrisiteit, word ander faktore soos die beskikbaarheid van steenkool en uraan en die vergelykende koste van kern en steenkoolgebaseerde elektrisiteit as die belangrikste parameters beskou wat tot nog nie voldoende gekwantifiseer is om te besluit oor die tydsberekening en die omvang van kernenergie in Suider-Afrika nie.

INTRODUCTION

An integrated approach to energy development is an inherent feature of energy policy formulation. This is obvious in the implementation of national policy on a where decisions are trade-offs shaped to a large extent by non-energy priorities, such as national security, socio-economic consideration or for that matter environmental issues, to name but some.

The nuclear industry, in particular, is the most internationalized of all energy industries, aspects such as nuclear safety, waste disposal and a non-proliferation of nuclear weapons being on the negotiating tables around the world. It has the largest government involvement placing it firmly in the realm of public decision-making. As far as South Africa is concerned the imposition of sanctions and a virtual cut-off from international expertise have added a further dimension. Possible decisions concerning the commercialization of ESKOM further complicate the development of longer term nuclear energy strategies. Additional uncertainties arise when present parties to a negotiated settlement for a future South Africa, such as the African National Congress, publicly states: "that there is no need to use nuclear power to generate electricity in South Africa because alternative sources of energy exist in huge coal deposits (which can be used with the correct technology) and abundant solar energy."[1]

A new socio-economic order with an emphasis on energy for all, a dedicated thrust to the improvement of quality of life for all of its peoples and a quest for a low-cost and affordable energy policy is seen to be emerging. On the other hand it is equally clear that for South Africa to continue developing in the years ahead, we are facing a future shaped by new and high technologies with an ever increasing demand for skilled manpower and a dedicated thrust for policy-directed research and development, as well as a dire need to share international expertise, a new world in which nuclear power has a significant contribution to make in order to satisfy increasing energy demand to provide sustainable development for the future.

Before the variety and abundance of Southern Africa's energy resources are discussed, with particular reference to the role of nuclear energy it is appropriate to reflect on the anticipated future energy needs and the guidelines necessary for the management of demand and supply side options and the various initiatives which are available.*

FUTURE ELECTRICITY DEMAND AND SUPPLY OPTIONS

A credible electricity load forecast is of critical importance in the development of a long-term energy strategy. Estimates of electricity demand in the past have, for more reasons than one, been optimistic with the anticipated growth in demand not materializing as has been expected. Taking into account reserve requriements, ESKOM presently has excess capacity of more than 4 300 MW.[2] With a projected growth rate of 4% per annum and presently committed capacity and life extension programmes, no new plant is envisaged during this decade. Due to lead times of 10 - 12 years, decisions will of course have to be made earlier, probably within the next year or two. Apart from the difficulty of assessing what the new South Africa would look like, politically/economically and in particular from a energy or electricity demand point of view, the decision for the implementation of new plant will be the most complex yet.

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*The views expressed in this paper are the authors' and not necessarily those of the National Energy Council.

DEMAND SIDE OPTIONS

Some of the options and initiatives that will have to be considered for the Nineties, many of which are already in place, are:

DEMAND SIDE OPTIONS AND INITIATIVES

1990 - 2000: **Excess Capacity Management**

- Promote load growth
- Promote off peak sales
- Promote electricity for all concept
- Substition of electricity for other carriers
- Provide excess electricity for an added-value export drive

Demand Conservation

- Follow a least-cost energy strategy
- Develop and introduce conservation programmes
- Introduce cost-based time-of-use tariffs
- Involve public and industry to increase efficiency in electricity usage
- Promote cogeneration demonstration projects

After 2000: Comprehensive Demand Management Strategies

SUPPLY SIDE OPTIONS

Options for beyond 2000 when new plant would be required are:

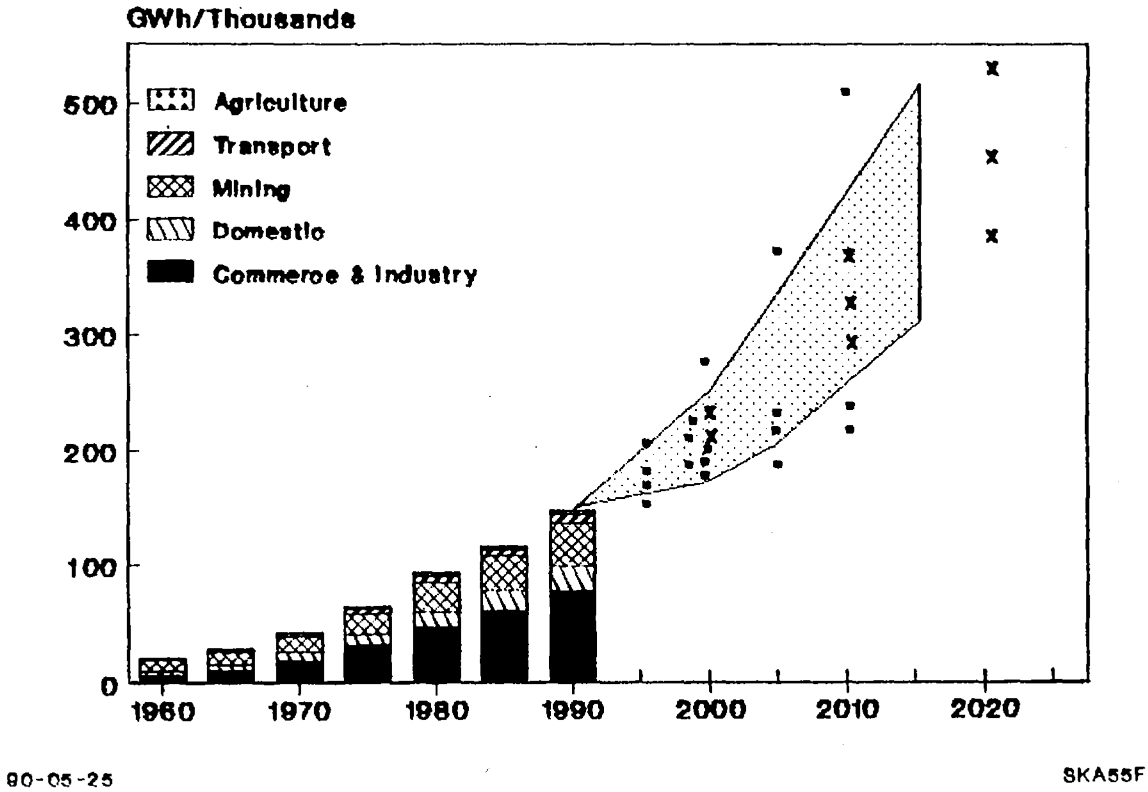
SUPPLY SIDE OPTIONS AND INITIATIVES

2000 and beyond:	**New Generation Plant/Supply**
South Africa	. Availability improvement of existing plant . Life extension of plant not in service . Small scale supply/cogeneration/discard utilization . New coal-fired plant . Bridging nuclear programme . New technologies, e.g. combined cycle . Natural gas development . Renewable energy applications (localized)
Southern Africa	. Botswana (coal-fired plant) . Namibia (Kudu natural gas and Kunene Hydro Scheme) . Mozambique (natural gas and Cahora Bassa) . Southern Africa hydro-electric resources

FORECASTS OF ELECTRICITY DEMAND

Forecasts of the demand for electricity for the RSA for the next three decades, i.e. to the year 2020, vary widely as may be expected.[3] The following compilation indicates the envelope which is presently adopted by ESKOM for strategic planning, the rate wide variation of other forecasts for electricity demand depending on what view or scenario was taken at the time (squares), and, the range of forecasts (crosses) derived from the NEC's ENVRAAG-model which was developed by the CSIR under contract to the National Energy Council which falls within the ESKOM envelope but tending to be more conservative. It is evident that the range of load forecasts is too large to be used for decision-making at this time.

Forecasts of RSA Nett Consumption of Electricity
(1995-2020)



It is important that all of the available methods of forecasting - mathematical modelling, environmental scanning, customer surveys, demographic trending - will have to be used in an attempt to develop realistic electricity demand scenarios for a new South Africa to ensure that adequate, but not excessive supply is available timeously in future. With so many options of smaller and diversified tranches of supply instead of e.g. only large blocks of coal-fired plant as in the past, a more dynamic and hopefully closer, match between demand and supply of electricity may well be realised in future. With a demand-driven approach and an appropriate management programme in place, the chances of the capacity excesses of the past are less likely. What is clear from present forecasts though is that we are facing a situation of increasing demand that could double early in the next century. Present projections of future economic growth rates and the structure of the economy remain the major factors of uncertainty.

The availability of the known energy resources of Southern Africa that may be considered for future base-load electricity supply with particular reference to the role of nuclear energy will now be assessed.

THE ENERGY RESOURCES OF SOUTH AND SOUTHERN AFRICA

The known resources of South Africa used for base-load electricity generation are all finite fuels the most important of which are coal and, at present, to a much lesser extent uranium yielding 89,6% and 7,7% respectively of the electricity sent from the ESKOM system during 1989[2].

It is therefore of critical importance to future strategic planning both on a national as well as a regional level, to assess what the **availability and cost** of indigenous coal and uranium reserves for the generation of electricity are.

At the same time there are a number of alternative sources of electricity supply which require consideration, the most important being the harnessing of the vast hydro resources of Southern Africa, an option which is featuring so prominently in ESKOM's vision of the future development of the sub-continent of Africa. This is not considered in any detail in this treatise but will no doubt feature in decisions yet to be made particularly when further base load plant is considered by ESKOM for the earlier part of the next century. It therefore does not feature in the present round of decision-making for new plant by 2000. Other options that may come into play in deciding what the nature of the new plant for additional base load supply by the year 2000 would be, could be an enhancement of the present Cahora Bassa Hydro-electric Scheme in Mozambique, new coal-fired plant in Botswana and the potential of offshore natural gas and additional hydro power from the Kunene Scheme in Namibia.[4] Various options for the utilization of offshore gas along the south and west coasts of South Africa, utilising e.g. combined cycle plant or cogeneration, may also feature. **However, regarding decisions for new plant by the year 2000, coal and uranium are considered as the only major players in the generation of base load electricity.**

COAL

Resources and Reserves[5] - Latest estimates of South Africa's coal resources, by far the largest in Southern Africa, which incorporated a comprehensive re-assessment of the Waterberg coalfield, amount to a total *in situ* resource of 121 000 Mt and extractable reserves of 55 000 Mt. The Waterberg coalfield contributes about 46 per cent and 28 per cent (or 15 400 Mt) respectively.

Availability of Coal Reserves[5] - It is however, important to note that the amount of coal that could be available for use as future power station feedstock has, however, never been adequately quantified on a national level. This is of course in itself a difficult and complex exercise since there are many variables over time that have to be considered. It is therefore of critical importance to set up a model which includes aspects like:

- The multiple end-use claim of different users.
- The multi-product concept based on coal from the same source used for the generation of electricity, metallurgical applications, synfuels and chemical production and for exports.
- The availability of large blocks of reserves which are required to support future mega power stations *viz a viz* the identification of the more prevalent smaller blocks of reserves that could support smaller generating sets.
- The introduction of new technologies for power generation which may change the requirements for reserve block size.
- Environmental constraints which may reduce the availability of coal reserves for electricity generation.
- The geographic distribution of reserves with respect to infrastructure and the availability of water.
- The economic viability of the transportation of coal versus tied collieries
- The sterilization of reserves by surface infra-structural developments.

If one considers the uncertainties of future demand for electricity it is evident that an integrated and regional approach to the assessment of coal resources is necessary for the development of a flexible longer term strategy.

Availability of Coal Reserves for Electricity Generation - Future coal-based generating capacity for the RSA has been estimated from recent offers of 21 000 Mt to ESKOM as well as the 8 500 Mt dedicated to installed and planned capacity of

42 000 MW.[6] A potential therefore exists for an additional 96 000 MW of coal-based capacity (e.g. 24 x 4000 MW stations), all of which would be located within the Eastern Transvaal Highveld.

To gain perspective from an overall energy resource allocation point of view, this total of 29 000 Mt not only represents more than 70 per cent of the known reserves of low-grade bituminous coal in the country but indeed all of the presently known coal reserves of the Eastern Transvaal Highveld; a region which not only provides nearly 80 per cent of presently coal-based electricity, but more than 90 per cent of South Africa's coal exports and 80 per cent of coal for other local uses, including all of South Africa's synfuel production*.

A FUTURE COAL STRATEGY

It must be clear that virtually unmanageable stresses in coal utilization may have to be contended with if all, or most of the available coal in the Eastern Transvaal, is dedicated to electricity generation *per se*. Resolution of priorities to claims of land for agricultural and infrastructural development as well as for the siting of a further 24 large power stations with the associated mines and transmission lines could well prove to be an impossible task. Even with the present twelve power stations located there, the Eastern Transvaal Highveld has become a region with a strong air pollution/environmental focus.

*Since coking coal, anthracite and hihg-grade bituminous coal are not used for electricity generation in South Africa, these should be excluded from the known extractable reserves of 55 000Mt, hence a total of 42 000 Mt of low-grade bituminous coal remans which could be considered inter alia for the generatio of electricity. The 21 000 Mt, offer plus the 8 500 Mt already committed represent 70,2 per cent of this total.

There is thus a real need for:

- greater emphasis on a balanced approach towards economic development and environmental issues
- planning on a realistic resource allocation basis both from an energy as well as a land use point of view
- early selection of power station sites and transmission line routes taking into account future infrastructural development
- addressing the increasing amounts of coal ash produced by power station and the like and the discards produced in particular by the coal export industry*
- a complete update of the National Coal Data Base with particular emphasis on economic mineability and end use

The coordinated and integrated development of all the resources of the Eastern Transvaal Highveld is of national importance and not only of concern to the energy and mining sectors of the economy. It is of vital importance to determine all of the strenghts and weaknesses concerning future coal availability since this will determine to what extent coal will remain the most important source of electricity in years to come. At the same time this will define the window of decision-making for the timely phase-in of a nuclear programme to support coal in providing base load demand.

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*Apart from the annual production of discard coal and rock wastes of more than 40 Mt representing to date some 400 million tons dumped on the surface, some 22 Mtpa of powder coal ash (fly ash and bottom ash) are generated by power stations and the industry.

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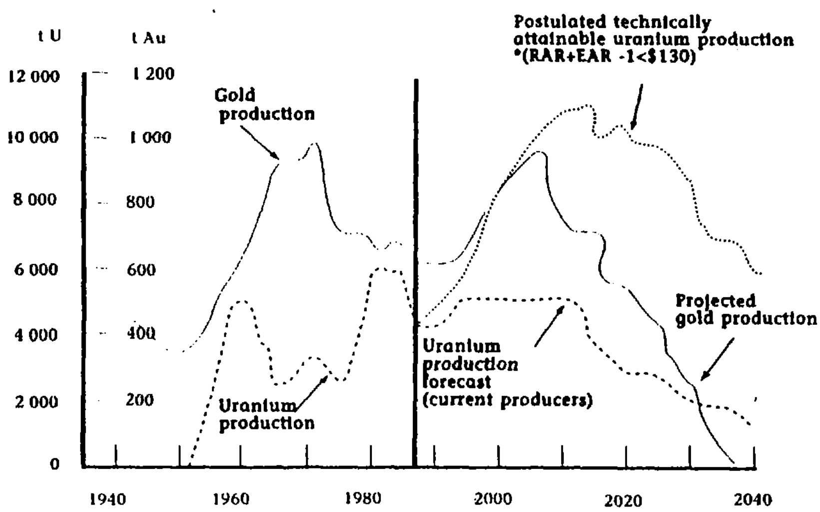
URANIUM

Reserves, Production and Nuclear Fuel[7]- Uranium concentrates in South Africa occur in five geological environments. Of the low-cost reserves (recoverable at a cost of less than US $80/kg U), 85 per cent are in Precambrian gold-bearing conglomerates and mine tailings dumps. South Africa's resources of uranium are estimated at 432 500 t U (1989) in the categories less than $130/kg U and are believed to be the second largest in the Western World.[8]

South Africa's historical gold and uranium production, and an estimate of uranium production capacity to the year 2040



* Reasonably assured resources + estimated additional resources - reclaimable at <$130/kg U

South Africa's uranium output peaked in the late 70's following a significant increase in price. A marked decline in world demand since then resulted in a drop of output to 3 451 t in 1989.[9] It is estimated that approximately 90 per cent of South Africa's uranium production is presently exported.

The first locally manufactured fuel elements were delivered to the Koeberg Nuclear power station in late 1989. Although fuel is only provided to one of the two Koeberg reactors, the enrichment plant at Valindaba is designed to meet the needs of two Koeberg sized power stations, *viz* 1960 MWe x 2 = 3 920 MWe.[10]

Availability of Uranium - The single most important constraint in the future availability of uranium resources in South Africa for the manufacture of nuclear fuels is to what extent and at what rate the RSA gold production declines in future. A forecast based on information available during the mid-Eighties reflecting an optimistic view at the time indicates a sharp drop in gold production at approximately 2005 to virtually zero by 2035[11]. As far as uranium production capacity is concerned, based on current producers, a levelling off at around 5 000 t U/yr for the period from the year 2000 to 2010/15 has been anticipated followed by a marked and continuous decline to about 1 000 t/yr by 2040. Considering that extensions of the Witwatersrand gold reefs are being discovered with new mines being developed and assuming higher gold and uranium prices, this scenario could be well realised. On the other hand continuation of the slump in the gold and uranium market could result in a significant decrease in the availability of uranium in the early part of the next century.

A FUTURE NUCLEAR ENERGY STRATEGY

The important point from a longer term energy planning view is that as much clarity as possible should be obtained on the impact of a decline in the RSA's gold production before embarking on a large scale nuclear programme - should this be founded solely on indigenous uranium resources. If the forecasted decline in uranium output during the period 2005 to 2030 do indeed materialize and this would coincide with the implementation of a large scale nuclear programme at the time, domestic supply of uranium as a byproduct from gold mining could be inadequate to sustain this. Indications are that world uranium prices during the Nineties will remain at their current low levels in real terms thus providing little incentive for a resurge in exploration activities[12]. Advances made in nuclear technology, like the large-scale introduction of breeder reactors, could of course change the picture.

If it is accepted that only nuclear energy could supplement coal in the generation of future base load and that South Africa, for reasons mentioned before, may have insufficient uranium reserves to sustain a long term nuclear programme, various possibilities exist for importing uranium from e.g. neighbouring Namibia, one of the largest producers in the world.

An option that has been proposed for the next round of base-load plant by the year 2000 and which warrants further consideration, is to proceed with a **bridging programme** at the Koeberg Nuclear power station by installing additional reactors.[2] This could *inter alia* provide for a smaller tranche of additional capacity leaving room for additional external supply, coal-based or hydro, from other sources in Southern Africa. Such a programme would have the additional advantage of the further utilization of existing fuel production capacity at Valindaba, as well as the stimulation of further research and development in fuel fabrication, particularly as far as cost reduction is concerned. The Koeberg site would be optimized and experience would be gained in the construction of future nuclear power stations.

Before any decisions are made on a future nuclear programme, including the bridging option, it is of critical importance to determine the real comparative costs of coal and nuclear-based electrical energy. This includes consideration of future coal-related environmental issues, particularly technologies which would add to generating costs, as well as the development of lower cost new nuclear systems characterized by safer, simpler and standardized designs having a high degree of reliability and longer lifetimes.

As far as the other countries in Southern Africa are concerned, the availability of vast hydro-power and other resources seems to preclude the nuclear option.

CONCLUSION

An integrated approach to electricity supply is of critical importance for the formulation and implementation of appropriate future strategies. In order to do this a credible range of demand scenarios have to be developed taking into account energy as well as non-energy related parameters. As far as the supply side is concerned a wide range of options and initiatives exists which together with demand side management and cogeneration will have to be considered to achieve a least cost energy strategy.

The formulation of an electricity strategy is an inherent part of national energy policy. It is therefore of vital importance that all of the key players, including the public, should be involved in the development of a future nuclear energy strategy.

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