“Planning for the future: The energy question”

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Paper presented at the Harold Wolpe Memorial Trust’s 52nd open dialogue

25 May 2006
Leslie Social Science Building, University of Cape Town

When this ‘dialogue’ was first proposed some months ago, I thought it was to be a nuclear / anti-nuclear affair, familiar territory. When it was advertised, however, the title had broadened to cover the whole energy picture. I have therefore had to dig around in less familiar ground. What I have now realised makes me feel as though I have joined Alice in Wonderland. I’ll explain as I go along. I will look at the situation that faces South Africa and at what Eskom will have to build in the next 20 to 40 years and at the options we have. I acknowledge there are downsides to nuclear power, as with all major power generation systems, but I believe nuclear is the only way to go. I will address the real and perceived shortcomings, necessarily briefly, at the end of this talk.

South Africa’s electrical energy is now supplied by the equivalent of ten large 4000MW coal-fired power stations. All are scheduled to shut down by about 2040. By then, the demand (if the past is a guide) will at least have doubled, so by then we must have built the equivalent of twenty more large, coal-fired power stations.

Eskom is now choosing a site for the first. It will probably start up between 2012 and 2014. For 30 years thereafter, the equivalent of two large power stations must start up every three years. Each will cost over R30 billion. This seems hardly credible. I start to think about Alice.

In fact, surely, existing power stations will have to be operated beyond their design life spans. If 60 years rather than 40 is achievable, the equivalent of one large power station will be needed every two years, and so on at an ever-increasing rate until energy prices enforce an increasingly drastic change of lifestyle.

‘We are going to have to make a big leap towards a different kind of world’. That was the message in an article in National Geographic magazine in August 2005. The message is that energy is going to be in very short supply and there will surely be more than enough room for all forms of economically feasible power generation -- and we need it quickly.

Options

The options we have **are c**oal, oil and gas, hydropower, renewables and nuclear. Let’s look at each of these.

When it comes to coal, according to DME data, we have reserves of 28,6 billion tons which is 10% of world reserves and places us sixth in the world behind the USA, India, China, Russia and Australia. Another estimate from a different source is 48 billion tons extractable. Eskom burns 140 million tons per year, i.e. 2,8% of coal burnt in the world, but total SA use (including SASOL and export) is 250 million tons. At our present rate of use South African coal will last between 100 and 200 years. The quality and accessibility of the coal will, however, deteriorate and it will become increasingly difficult to find coalfields large enough to support a power station for 40 years, seeing that about 500 million tons is required. One local energy analyst considers that, effectively, we have coal only for the next fifty years.

The message here is that coal is not sustainable in the long term. We'll still have to use it -- but cleanly please -- and wean ourselves off it over the next several decades. We must surely research clean ways of burning, such as coal gasification and even look at CO_2 sequestration If so, be prepared to pay! (See action list at the end of these notes.)
Other options are oil and gas. It seems to me that a very dangerous world situation is building up. Four times as much oil is being used as is being discovered. Gas is not too many years behind. There is an imminent American and European over-dependence on Russia and the Middle East, while the UK is moving from producing 80 to 90% of its oil and gas requirements to importing that amount. Rather soon there must surely be an acute world shortage.

SA assured reserves (Kudu, Ibhubesi (West Coast), Mossgas, Pande) are tiny, say 4,7 TCF (1TCF = 10^{12} cubic feet), which is equivalent to 5 300 Petajoules of energy (private communication, Jack Holiday, energy consultant)**.** This would power one 4000 MW power station for just 23 years.

This means that severe international competition for diminishing resources is imminent and that price escalation is inevitable. South Africa must become as independent as possible in respect of oil and gas. This may require further exploration. We surely shouldn't burn what little we have to make electricity. It should be used instead as feedstock for liquid fuel for transport. We should expand SASOL greatly and make ethanol for the same purpose.

Hydro-electric, wind and solar power
There is little potential for hydroelectric power (less than 5% now) in South Africa . The nearest large water source that could be used is the Inga Falls, 3 000 km away on the Zaire River which could be developed to produce about 40 000 MWe. We should work to establish an African grid that extends to the Inga Falls if it is politically feasible. It is possible that we could obtain 10% of our electrical energy from there.

South Africa has moderate wind potential. The main problem is that windmills are only about 20% available in the wind fields existing in this country. In other words, a windmill designed to generate 1 MWe will do so for only 20% of the time - output at lesser wind speeds falls sharply. A windmill that generates 1 MW (such as those at Klipheuwel north of Cape Town) in a good wind generates much less for most of the year. It is therefore necessary to provide a coal or nuclear backup power station. If a backup plant capable of virtually full-time operation must be built, why build the windmills in the first place? Consider Denmark (population seven million). The Danes are able to use mountain reservoirs in Norway for pumped storage. When Norway can't supply them on windless days they import from larger and wealthier neighbours such as Germany and Sweden. South Africa cannot do either. Wind use in SA is therefore severely limited. There is no point in discussing wind for bulk energy any further until the storage problem is solved. Maybe the 'hydrogen economy' is a long term solution.

There are a number of secondary problems. The cost of wind-power is at least double that of coal or nuclear energy, even in Europe (reference: Royal Engineering Academy). There is also the visual impact. Koeberg's annual output is equivalent to 7 000 Klipheuwel-type windmills. Constructed in a line with the requisite distance between them (five to seven times the blade diameter), these would stretch from Cape Town into Natal.

The amounts of raw materials needed are far greater for wind machines than for nuclear power plants, approximately ten times as much steel or copper and twice as much aluminium (data from Stuttgart University).

The amount of power generated is relatively modest. A two-metre diameter 'home' windmill in a windy location will generate about 1,3 kW (intermittently) giving, on average, about 6 kWh/day. Such a windmill on every dwelling in South Africa, say ten million, all assumed (incredibly) to be in windy locations, would generate 22 GWh/y, which would be 10% of the country's usage of 223 000 GWh/y.

For these reasons wind cannot help South Africa significantly at this time. Nevertheless, research should be done into possible large pumped storage sites and other power storage technology.

The picture is very different when we look at solar power, something for which South Africa has excellent potential. An area of the Northern Cape 40 km square half covered with solar collectors could power the entire country – if we were able to store energy for night and peak time use.

Storage is, however, the significant problem. As in the case of wind, backup is necessary, although not to the same extent because solar energy is more predictable and is generated during the day. Again, the storage problem must be solved before solar power can become useful for bulk generation.

Among secondary problems is the very high cost at present of thermal solar collectors, even more for PV systems. The PV energy payback time is currently seven to 12 years, according to data from Stuttgart University.

Solar power requires the massive use of construction materials, water and toxic chemicals. Like wind, the energy is diffuse. A solar panel 1 m^2 will intercept about 6 kWh per day and generate about 1 kWh/day. Assume, incredibly, that 20m^2 of solar panels is installed on each of 10 million dwellings The power generated would be 73 000 GWh/y, or 33% of current SA needs. The cost would be astronomical.

Regrettably, therefore, solar cannot help significantly at present. We should keep on researching because we are surely going to need it. Right now it should be used to the greatest possible extent for off-grid applications, particularly for heating water.

Biomass is another option on which hopes have been pinned. A drawback is that large area of fertile land required. The European Union's biomass target for 2010 is to have 5,75% of all EU vehicles powered by bio-fuels. The equivalent land area required would, however, be about 33% of the United Kingdom. All available land in South Africa should be used for sugar or mealies to produce ethanol for vehicles.
Wave, tide and ocean currents have all been touted as possible energy sources, but it is early days yet for these technologies and we will have to monitor world research on what is being attempted.

The inescapable conclusion is that renewable energy sources cannot do the job or even, in South Africa, help very much. Even speculating about their use de-emphasises the magnitude of the imminent energy problem. Solar is there for the very long term and, for the medium term, we should use Inga Falls to the maximum extent that is politically possible.

Nuclear
It appears that we have to stick with coal although that means using 13 million tons for every large power station every year. But coal must be supplemented by nuclear as fast as we can go. Nuclear power is feasible. We have the uranium, 295 000 tons of it, enough to last us for 400 years at our present rate of consumption. These reserves place us fourth in the world behind Australia, Kazakhstan and Canada. Neighbouring Namibia is fifth. We are 10th in world production of uranium. Breeder reactor technology, which allows seventy times more energy to be extracted from a given mass of uranium, will make the uranium reserves essentially infinite. Thorium, more abundant than uranium, can then also be used as feedstock. One can even consider extracting uranium from seawater, which makes it an infinite source.

The cost of nuclear power is now competitive with that of coal, at least in Europe (reference: UK Royal Academy of Engineering). South Africa also has the technical experience in nuclear power generation.

The clear conclusion is that:
- There is at present no viable alternative for bulk generation to coal and nuclear
- We must continue to burn coal, but as cleanly as possible
- We need to increase the percentage of nuclear power as fast as possible
- We should research renewables for use as off-grid applications.

A closer look at nuclear
Nuclear energy has the great advantage that it can provide all the electrical energy we need, virtually for ever. There are, inevitably, negative aspects that must be addressed. The most important of these, in my view, is the connection, such as it is, between nuclear energy and weapons proliferation. The next in importance is the remote possibility of major accidents. We should also consider radiation exposure to operators.

The disposal of high-level waste is not an urgent or a particularly difficult technical problem but does concern the public, a situation that the nuclear industry has handled very badly. Routine effluents constitute a much lesser issue but seem to evoke disproportionate concern in the anti-nuclear lobby. These issues are therefore addressed briefly below.

Other issues such as the disposal of low-level waste at Vaalputs and the transport of radioactive materials are minor, even trivial.

Weapons proliferation
Neither new nor used fuel from Koeberg or the PBMR is the slightest use for weapons production. The issue is the possibility of nations hiding a weapons programme behind a peaceful power programme, of which there are several examples. This is a political problem. All uranium enrichment and spent fuel reprocessing activities must be bought under strong international control. The Global Nuclear Energy Partnership (GNEP) initiative launched by America this year hopefully is a start. Resolute political will is going to be required as more and more nations take advantage of nuclear technology.

Nuclear accidents, including terrorism
Chernobyl showed the destructive potential of a large nuclear reactor and the total inadmissibility of any such event in future. As with airliners, reactors become safer with time. In Generation II reactors such as Koeberg, a melt-down event is already

highly improbable and would be contained or at least mitigated by the safety systems as happened at Three Mile Island. In Generation III reactors such as advanced PWRs and BWRs now being built in Japan, the Westinghouse AP-1000 and the EPR that will replace the French fleet, the probability of the event and the likelihood that it will be contained are further much improved. In the PBMR, the first Generation IV design, the possibility of meltdown and therefore of significant radioactivity release is eliminated entirely.

Operators and maintenance staff

Analyses of mortality records show that the overall death rate among radiation workers is less (11% less in the case of 125 000 UK workers) than that for peer groups in other industries. This is probably due to heightened medical supervision. It is easy to show that, even on the most pessimistic interpretation of radiation effects -- the Linear No-threshold Theory (LNT) -- the risk to operators due to radiation is much smaller than the risk they face of fatal, non-nuclear industrial accidents.

High-level waste

This must surely be the most emotive issue concerning nuclear generation. It is, however, neither an urgent nor a technically difficult problem. High-level waste must be stored for several decades to allow fission product heat to die away before it can finally be disposed of. France, where 78% of electricity is nuclear, has recently announced plans to have its first waste repository in operation by 2025. The first choice of the French authorities is currently to dispose of the waste in tunnels in deep clay deposits. Most countries are likely to use crystalline rock or, possibly, in the case of Germany, salt deposits.

Since radioactivity dies away with time, the accepted policy among waste specialists is to contain the waste until the radioactivity has fallen to a low level and then to demonstrate by careful and conservative analysis that radioactivity in groundwater in the far distant future will be negligible. Several countries have now demonstrated by analysis that this is possible.

What is meant by '…to a low level'? It should be recognised that uranium *before it is mined* constitutes a degree of risk to local populations. The uranium gradually decays into radium and radium into radon gas. Radium and radon move with groundwater to the surface, where radon decay deposits radioactive daughter products deep in our lungs and delivers at least half the natural radiation to which we are all exposed. In some places (for example Ramscar in Iran) local populations are exposed to much higher radiation levels due to radon than are allowable for radiation workers at nuclear power stations.

The American Environmental Protection Agency recently demonstrated, in connection with the Yucca Mountain repository, that the hazard due to radioactivity in spent fuel made from that uranium drops to below the hazard represented by the unmined uranium in less than a thousand years. The policy is therefore to contain the waste by engineering means for, say, 10 000 years, i.e. until it has fallen to a very low level, and to accept that what is left may thereafter move very slowly out of the repository area with groundwater, albeit in negligible concentrations.

Consider South Africa's most highly toxic, non-radioactive waste. It stays toxic for ever. It is disposed of in concrete cells within waste disposal sites. The local environment, unless the Minister decrees a longer period, must be monitored for just 30 years. It is not here suggested that radioactive waste should be dealt with in this way. It does suggest, however, that a sense of perspective should be maintained.

Routine effluents

The length of this section is entirely out of proportion to the relative importance of the subject matter. It is a reflection of the significance afforded to it by anti-nuclear movements.

The internationally established exposure limit for the general public around a nuclear installation is 1 mSv/y (one millisievert per year) compared with 20 mSv/y for radiation workers. The South African limit is 0,25 mSv/y. The calculated annual exposure (much too small to measure) to the most highly exposed individuals around Koeberg is around 0,005 to 0,01 mSv with a maximum to date of 0,02 mSv. Suggestions that effluents from Koeberg are actually harmful to health go so far as to imply incompetence or collusion between the power company and the safety authority -- in fact between the power companies and safety authorities in over 30 countries operating nuclear power stations.

Nevertheless, anti-nuclear groups persist in trying to establish the existence of ‘clusters’ of leukaemias and other conditions due to radiation around nuclear facilities. Their survey results, however, are systematically refuted and condemned as incompetent and irresponsible by official health and safety organisations. See, for example, the comments of COMARE, the Committee on Medical Aspects of Radiation in the Environment, on the work of Green Audit in the UK. Their work, despite such ‘official’ condemnation, is repeatedly quoted by green movements.

Strontium 90 is often portrayed as the leading villain of the piece. This is nonsense. Consider the following.

1. Atmospheric weapons testing, mainly in the 1960s, put some 622 PBq of Sr 90 into the atmosphere. (1 PBq = 10^{15} becquerels, 1 GBq = 10^{9} becquerels, 1 MBq = 10^{6} becquerels). The worldwide fallout would therefore have averaged about 1,2 GBq/km^{2}. This corresponds with measured values, for example 2,2 GBq/km^{2} in parts of Florida.

Koeberg records show that in only one quarterly sampling period (in 2002) has Sr 90 been detectable in gaseous effluent in the stack. About 0,2 MBq of Sr90 was released in that year. This compares with the average annual release of Sr 90 to atmosphere from over a hundred American reactors is 0,37 MBq each). (0,1 GBq has been released from Koeberg into the sea). Assume 0,37 MBq falls out every year for 20 years within 10 km of a reactor. Average ground contamination: 24 000 Bq/km^{2}. This is 50 000 times less than the world average (1,2 billion becquels, see above) due to bomb testing in the 1960s. If Koeberg fall-out is of concern, how can the world have survived Sr 90 levels a million times greater?

2. Now assume that all the Sr90 emitted from the average American reactor in a year (0,37 MBq, less than one ten millionth of a gram) is caught and you are obliged to swallow it. How worried should you be? A health physicist can easily estimate that your effective radiation exposure (mainly to the bone) over the rest of your life will be about 14 millisieverts (mSv). This is not worrying. The allowable effective annual exposure for radiation workers is 20 mSv. If you were forced to inhale the material as a very fine insoluble powder, your lifetime exposure would be 130 mSv, giving a less than 1% risk of cancer in later life – to add to your present 20% risk.

Practical problems in implementing a large nuclear programme

World capacity: Very little nuclear plant has been built in the West since Three Mile Island and Chernobyl. The nuclear industry has consolidated and manufacturing capacity is much reduced. However, there is clearly a renaissance brewing. There will be a manufacturing bottleneck and consequential escalation of price. The first problem to hit may well be a world shortage of steel ingot. South Africa should consider entering into a long-term relationship with a selected manufacturer now to secure its place in the queue.

There is an energy crisis coming. I believe society does have to change, but is anyone in this country thinking things through and asking how to make this transition easier?

Cost: As indicated above, a large (4 000MW) coal-fired power station would now cost R30-40 billion. The same sized ‘conventional’ nuclear station will cost significantly more, PBMRs about the same as coal. The National Treasury must surely ponder these things.

Human resources: It appears that the country is finally waking up to the overall skills shortage. Is enough being done? Can enough be done?

In conclusion

Our title was: ‘Planning for the future: the energy question’. My plan is to:

- Examine the feasibility of commissioning the equivalent of a large coal-fired power station every year or two. Consider the resource needs, as well as the social and economic implications of not doing being able to do so.
- Develop ways to burn coal cleanly, for example coal gasification. Extract uranium from coal if concentrations warrant it. Monitor research progress on CO_2 sequestration.
- Look for more oil/gas. Do not burn it! Greatly enlarge SASOL. Make Ethanol from biomass. Encourage electric-powered vehicles. Research fuel cells and hydrogen production for energy storage.
- Continue cooperation to secure power supply from Inga Falls, to the greatest extent politically possible.
- Search for further large pumped storage sites, if any. Research other power storage technology.
- Research solar panels.
- Monitor world research on wave, tide, ocean current technologies.
- Enter into long-term relationships with a preferred reactor manufacturer and others to secure places in the likely queues.
- Consider the cost and human resource implications of all this.

Finally, it appears to me (and I am not normally a doomsday prophet) that a protracted energy crisis driven by spiralling transport and electrical energy costs is inevitable in the next few decades. Profound lifestyle changes appear unavoidable. I am by no means convinced that enough being done by government, industry and academia to think the situation through and to prepare for it?