The economic risk to electricity consumers of the Pebble Bed Modular Reactor

by

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1. Introduction

The objective of this report is to identify the measures that the National Electricity Regulator (NER) and the body that will succeed it on April 1 2006, the National Energy Regulator of South Africa (NERSA) must take to ensure that electricity consumers are not inappropriately exposed to the economic risk of the programme to develop and market a new design of nuclear power plant, the Pebble Bed Modular Reactor (PBMR). The PBMR is a highly risky venture, with a significant probability that these risks will be borne, inappropriately, by South African electricity consumers. Large sums of money have already been spent by Eskom, of the order R1bn (see Section 4.2), but, over the next 5-10 years, electricity consumers could be asked to finance investment in the excess of R10bn for the demonstration phase of the PBMR including the purchase of the demonstration plant (see Section 4.3 and 5.2) and R36bn for purchase of commercial units (see Section 5.3). Consumers would also be liable for the cost of decommissioning the demonstration plant and the commercial plants. No estimates for the cost of decommissioning exist but in view of experience elsewhere, it is likely that the cost of decommissioning would be of the order of several tens of billion Rand. It is essential, that NER understands these risks and protects consumers from them. NER must make it clear to Eskom, before investment takes place, how it will treat investment in the PBMR project.

The NER states that its duties include its 'advocacy role'. NER states[1]:

> 'Utilities such as Eskom, Sasol, etc. cannot increase their regulated rates or alter their conditions of service until NERSA approves the new tariffs. To obtain approval, a utility must demonstrate that such a change is merited. The utility files an application with NERSA to "prove" that an increase is justified. The advocacy role requires that there must be an independent body to represent the side of the consumers during the tariff determination, especially the voiceless consumers.'

If NER does not examine the potential impact of the PBMR on consumers in its current (2006) price determination, it will not be fulfilling its advocacy role because it will not have required Eskom to demonstrate that costs from the PBMR programme are not being passed on, unjustifiably, to electricity consumers as increased prices.

Part 1 of this report gives a brief account of the PBMR project documenting the costs incurred so far and showing the serious escalation in cost estimates for the demonstration and commercial phases of the project.

In Part 2, this report shows in detail how the PBMR programme should be treated by the NER, in particular how the NER should ensure that excessive costs are not passed on to consumers through regulated prices.

1.1. The regulatory context

The context for this analysis is that in December 2005, NER published a consultation paper giving its proposals on the costs that Eskom would be allowed to charge in the period April 1 2006 to March 31 2009.[2] Eskom had requested real (over and above inflation) price increases of about 0.6 per cent per year for the 3-year period and NER foresees upward pressure on prices for the period from 2007-2020 due to the 'urgent need for new capacity and sources of fuel from 2007 onwards right through to 2020.' The PBMR programme is expected to make up an increasing proportion of new investment in generation, despite the fact that there are significant doubts about whether it would represent the cheapest source of new power generation.

A particular concern for the period to March 31 2009 is the removal in 2005 of the corporate distinction between Eskom Enterprises, the part of Eskom that owns the company that has developed the PBMR and the regulated parts of Eskom. Until 2005, Eskom Enterprises was a legally separate company from Eskom, albeit 100 per cent owned by Eskom. Eskom Enterprises' record was poor and investments of over R1bn, mainly in telecoms had to be written off in 2003. Until then, its separate legal status meant it was easy to insulate electricity consumers from these losses. However, now that it is simply a division of Eskom with no corporate separation from regulated parts of Eskom's business, there is a significant risk that losses in the Enterprises division will 'leak' into the regulated businesses. It is relevant to note that in the European Union, EU law requires that regulated companies are fully legally separated from other businesses to avoid this risk.

[1] http://www.ner.org.za/nersa_profile.htm#10
[2] NER (2005) 'Multi-year price determination of Eskom', NER, Pretoria. (http://www.ner.org.za/documents%5CPublic.pdf)

1.2. The author

The author has written a number of articles on the PBMR (see Appendix 1 for a brief CV and relevant publications). He has been involved in energy policy research for 30 years, including large amounts of research on nuclear energy policy and on the regulation of energy industries.

He was invited by the then Energy Minister, Phumzile Mlambo Ngcuka to address a ministerial workshop on the PBMR in 2000 in Pretoria. He was a member of an international team of experts appointed by the Department of Minerals and Energy to write a report (not published by the South African government) reviewing all aspects of the PBMR to inform a Cabinet decision on the PBMR (2001/02) and he wrote a report (2005) on behalf of the Legal Resources Centre on the history and prospects for the PBMR.

PART 1 History of the PBMR project

2. The PBMR project[3]

The main publicly available sources of information on the PBMR programme are:

- The Final Environment Impact Report ("FEIR") (PBMR, 2002b) prepared by the PBMR EIA Consortium for the Applicant, Eskom;
- The Detailed Feasibility Report or DFR (PBMR, 2002a) prepared by PBMR (Pty) Ltd.

The PBMR has been under development in South Africa since about 1993, although it was not until 1998 that these efforts were publicised. It was expected in 1998 that work on construction of a Demonstration Plant would begin in 1999 and be complete before 2003 to allow commercial orders soon after (see D R Nicholls, 2000). Eskom projected that the market would be about 30 units per year, about 20 of which would be exported. In April 2000, the South African Cabinet approved Eskom's continuation and completion of a Detailed Feasibility Study (DFS, PBMR (2002a)) on the proposed PBMR. Subsequently, Eskom formed a company, PBMR (Pty) Ltd to develop and market the technology. PBMR (Pty) Ltd foresaw four phases: research and development (already then completed), feasibility study (then underway), demonstration, and commercial application. Since then, the timetable has slipped so that the Demonstration Plant, to be built at Koeberg, is not now expected to be in service before 2010.

2.1.1. The commercial arrangements

The PBMR was developed within Eskom until June 2000. Then British Nuclear Fuels Limited (BNFL), a UK government owned company active in all major aspects of nuclear power including reactor sales and servicing, fuel manufacture and waste disposal became the first foreign investor in the project taking a 22.5 per cent stake in the venture. They were followed by the US electric utility based in Philadelphia, PECO, taking 12.5 per cent of the venture. Subsequently PECO merged with another utility, Commonwealth Edison, to become Exelon. Exelon left the project in 2002, but committed to pay its full share of the feasibility phase. The South African government-owned Industrial Development Corporation (IDC) took 25 per cent of the venture but reduced its stake in 2002 to 12.5 per cent.[4] This left 52.5 per cent with Eskom of which 10 per cent was reserved for an Economic Empowerment Entity, but this was not taken up. The agreement left all the shares in PBMR (Pty) Ltd in the hands of Eskom Enterprises, then a subsidiary of Eskom, but committed the partners to provide funding in proportion to their stakes in the business to the end of the feasibility phase. Then, the company would be reconstituted in preparation for the feasibility phase with the partners entitled to take a stake in the new company equal to their percentage contribution to the feasibility phase. The costs of development would be recovered as royalties from reactor sales.

2.1.2. The cost of the feasibility phase

The DFR (PBMR (Pty) Ltd, 2002a, p 19) reported that costs of development to end April 2001 were R437m. with a further R80m approved in May 2001. It stated that further funding had been approved in December 2001, but the sum was not specified. In the FEIR, PBMR (Pty) Ltd (PBMR (Pty) Ltd, 2002b, p 200) said that the total amount that had been spent on the PBMR to July 2002 was R684.2m and forecast that the total amount to take the project to the end of the feasibility stage (then expected at end 2002) would be R1013m of which R461m would be provided by Eskom.

However, in August 2003, Terblanche[5] stated that PBMR development had cost R1.5bn of which R550m had come from Eskom, a total of R240m from IDC and BNFL with the balance coming from Exelon. BNFL appears to have spent much less than it was required to, Exelon spent significantly more and Eskom a little less. The additional money had been spent on further design work and letting a number of design and supply contracts. Since then, expenditure has continued on a short-term basis but it is not clear who has funded it, or what the total development costs to date are.

Terblanche[6] indicated in 2004 that monthly costs were 'a lot more than' R50m even at the reduced level of activity that had prevailed since the completion of the feasibility phase. Assuming costs were just R50m per

[3] For a fuller account of the history of the PBMR project, see S Thomas (2005) 'The Economic Impact of the Proposed Demonstration Plant for the Pebble Bed Modular Reactor Design', Legal Resources Centre, Cape Town
[4] Nucleonics Week, October 6, 2005, p 1.
[5] Nucleonics Week, August 28, 2003, p 1.
[6] Financial Mail, March 26, 2004, p 14.

month this would mean the development costs to the end of October 2004 were in excess of R2bn. In October 2004, the government announced support of up to R500m for the PBMR venture to pay for running costs for the company and design development costs (turbine development and construction of a helium test facility were mentioned as particular requirements).[7] In February 2005, when the government's budget was announced, the government support had increased from R500m to R600m. It is not clear whether this government money was a loan or a grant or whether it represented an increase in the government's stake in the PBMR project. It remains uncertain who will fund the demonstration phase.

Substantial sums have been spent on developing the PBMR, about two thirds of which was South African public money. However, the next phase of demonstration will take the level of spending to a far higher level, currently estimated to cost R14.5bn, requiring at least *seven times* as much money as has been spent so far.

2.2. Economics of the PBMR programme

By its nature, the Demonstration Plant will not be an economic source of power. The issue for regulatory purposes is what the extent of the excess costs will be and who will bear these costs: taxpayers, electricity consumers or private investors? The main factors that must be considered are:

- The partners, especially foreign companies;
- Construction cost and cost of other new facilities required;
- The cost of capital;
- The plant's maximum electrical output;
- Operating performance especially reliability;
- Operations & maintenance cost, including fuel supply and spent fuel disposal;
- Decommissioning cost; and
- Operating life.

The analysis for the commercial programme must be much wider ranging and include:

- The economic competitiveness of the PBMR compared to other electricity generation technologies;
- The likely world market for the PBMR;
- The South African market for PBMRs.

None of these factors can be estimated with any precision at this stage and the analysis of risk and who will bear the cost of poorer than expected performance is particularly important.

2.3. Economics of the demonstration plant

2.3.1. The partners

Introducing partners to the venture has three main potential advantages: sharing of development costs; introduction of new skills; and access to foreign markets. The downside of having partners would be that any benefits to Eskom and the South African public would be diluted, so ideally any foreign partners should bring more than just finance to the project. Eskom's partners in the feasibility phase have fulfilled their obligation to the programme and have no further legal commitment to fund the programme.

Exelon's main potential contribution to the project was its promise to open up the North American market. Exelon committed to pilot the design through safety certification by the US Nuclear Regulatory Commission (NRC). Certification by the NRC (or a national regulatory authority with a comparable level of expertise and prestige) will be essential for sales to most markets outside South Africa, not just sales to the USA. Exelon also pledged to buy 10 commercial units and suggested they would buy 40 or more units in the first decade of the commercial phase. The 10 initial sales were the only apparently firm sales for the PBMR there have been (sales to Eskom were then conditional on it being the cheapest generation option). These sales would have been an excellent 'shop-window' for the technology for the potentially huge US market and would allow the setting up of reactor manufacturing facilities, which subsequent commercial sales could take advantage of. As an electric utility rather than a plant designer, Exelon's technical contribution to reactor design was limited but as an experienced nuclear power user, its input would have still have been valuable.

[7] Business Day, October 29, 2004 and Nuclear News November 2004 / Business News N°51 / 04

Exelon left the project in April 2002 and, while the FEIR explains Exelon's departure on grounds of it not wishing to be a 'reactor supplier' (PBMR (Pty) Ltd, 2002b, p 192), there seem to be additional factors behind their withdrawal. The decision to enter the venture appears to have been very much a personal one by the CEO of PECO, Corbin McNeil (later joint CEO of Exelon). When he left the company, the commitment to the PBMR was quickly withdrawn.[8] John Rowe, the new CEO of Exelon was quoted as saying: 'the project was three years behind schedule and was "too speculative,"'[9]. He also said: "a detailed review that Corbin and I started late last summer yielded a recommendation from the people in charge of the project that ...[operation and testing was] three years further out than we had thought a year ago." Since then, schedules have slipped substantially further, probably by more than a further three years.

BNFL entered the venture at about the same time as Exelon and their technical contribution appears to have been in fuel manufacture. BNFL would provide no significant advantages in terms of access to markets. BNFL has been in severe financial difficulties for a number of years. In fiscal year 2002, it lost £2.32bn (R25bn) and in fiscal year 2003, it lost £1.09bn (R12bn). It had liabilities of about £30bn (about R350bn) with few assets available to discharge these liabilities. In July 2003, UK government plans to part-privatise the entire company were abandoned and in April 2005, a major part of its business, waste disposal, reactor operation and reprocessing was taken away from it and placed in a new government agency, the Nuclear Decommissioning Agency. The UK government is currently reviewing the future of its other activities and has put its two main divisions, including the Westinghouse division up for sale and the likelihood is that BNFL will cease to exist soon. A shortlist of four companies bidding for it has been drawn up, including General Electric, Shaw Group, Mitsubishi Heavy Industries and Toshiba Corp and the successful bidder is expected to be announced early in 2006.

The current management of BNFL/Westinghouse cannot oblige the future management to carry through any commitment to participate in the demonstration phase of the PBMR. Terblanche has said that BNFL could take 10-12 per cent of the next phase or 25 per cent of the fuel business.[10]

IDC appears to have brought only finance to the venture. As it is owned by the South African government, in terms of risk reduction to the South African public, it contributed nothing. In 2002, with no public announcement, IDC reduced its stake to 12.5 per cent. Terblanche was quoted in August 2003 as saying the IDC would take no more than 12.5 per cent of the next phase.[11] However, following a government review in January 2004, IDC was expected to take a more prominent role in the project, and in November 2004, the CEO of Eskom told the Parliamentary Portfolio Committee on Trade & Industry that IDC would be replacing Eskom as project leader.[12] However, this plan now appears to have been dropped.

A number of other potential investors have been mentioned, but these appear to be highly speculative. In August 2005, it was announced that the government would take a direct 30 per cent stake in PBMR (Pty) Ltd. Eskom's CEO, Thulani Gcabashe, said his company's stake would dilute over time to around 5 per cent. IDC will keep 14 per cent and BNFL 15 per cent according to PBMR (Pty) Ltd. This leaves 36 per cent of the shares unallocated. On present evidence, it is unlikely that private investors, especially from outside South Africa willing to take the remaining 36 per cent of the project can be found. So, as a minimum, the South African public will be asked to pay for at least R9bn of the R14.5bn the next phase was forecast to cost in August 2005. If costs escalate or private partners cannot be found, the cost to the South African public will be much higher.

2.3.2. Construction cost and cost of associated facilities

Repaying the cost of construction of the plant has always been expected to be the major element in the overall cost of power from any nuclear power plant. Its importance has increased in the last decade as attempts to introduce competition to the electricity industry have increased the cost of capital raising the charge for repaying the construction cost.

The FEIR contains no information on the expected construction cost of the Demonstration Plant or the commercial plants. In 1999, Nicholls (Nicholls, 2000) forecast that the construction cost would be about US$100m (then equivalent to about R600m) for a single commercial module, presumably as one of 8-10

[8] 'Corbin was the cheerleader for this technology, and without him, it can't go forward.' Electricity Daily, April 17, 2002.
[9] Energy daily, April 24, 2002.
[10] Nucleonics Week, August 28, 2003, p 1.
[11] Nucleonics Week, August 28, 2003, p 1.
[12] Sunday Times, November 10, 2004.

units installed on a site. Nicholls[13] was quoted separately estimating the cost of the Demonstration Plant as double the settled down commercial cost with a further US$100m for a fuel production plant. The total cost of the Demonstration Phase was therefore then estimated to be US$300m or a little less than about R2bn.

In 2002, the DFS (PBMR (Pty) Ltd, 2002b, p 23) suggested some cost increases had occurred and the target construction cost for commercial units was now placed at US$1000-1200/kW. However, there appear to have been major cost increases. These have been masked by three factors. First, it is not clear whether the current cost estimates cover as full a range of costs as the original estimates, for example, if the cost of the first fuel load was omitted (conventionally this is included in the construction cost), the apparent cost would fall masking real cost increases. Also, it is also not clear whether the new estimates are now a cost or a price (i.e. including the profit). Second, there has been some depreciation (about 10 per cent) of the Rand against the US dollar between 1998 and 2004. However, the third factor is the most important. In 1998, the design was expected to produce a net output of 110MW but commercial plants are now expected to have an output of 165MW, an increase of 50 per cent. This would allow the cost of a module to rise by 50 per cent without increasing the cost per kW.

In September 2001, Nicholls[14] admitted the original schedule for the Demonstration Plant had slipped. He then projected start of construction for 2002, with completion expected in 2005 and commercial sales to begin in 2009. There was discussion about up-rating the output of the plant to 130MW to be achieved without significant cost increases.[15] In 2002, the DFR, (PBMR (Pty) Ltd, 2002a, p 50) stated the design could be up-rated to 137MW 'without a significant increase in cost'. This meant that costs per module could increase by nearly 20 per cent whilst still remaining within the US$1000/kW target.

In April 2002, Exelon withdrew from the PBMR venture[16], although it agreed to fulfil its commitment to fund the venture until completion of the feasibility study phase, then expected to be finished in September 2002. Forecast start of construction of the Demonstration Plant had by then slipped to 2004.

By May 2002, Nicholls[17] was much less precise in his estimate of the cost of the Demonstration Plant, estimating a cost of between US$2000-5000/kW. At the bottom end of the range, assuming a unit size of 110MW and US$2000/kW and an exchange rate of US$1=R6, this would translate into a total cost of R1.3bn, while at the upper end, with 130MW and US$5000/kW, it would translate into R4bn. It is not clear whether these estimates included the cost of a fuel production facility. Nicholls still adhered to the US$1000/kW estimate for commercial orders provided these were built in groups of 8-10 per site and only after 20 units had been sold.

By December 2002, the target output of commercial units had increased to 165MW, 50 per cent higher than originally planned. Nicholls[18] admitted that the US$1000/kW would not be achieved until 32 units had been sold. Further delays were announced in the programme. Earlier in 2002, the shareholders of PBMR (Pty) Ltd had expected to announce whether they would proceed beyond the feasibility stage by the end of 2002. This decision was postponed into an unspecified date in 2003 and appeared still not to have been taken in December 2004. In July 2003, the Demonstration Plant was expected to be 125MW with subsequent units producing 165MW.[19]

The main extra cost for the demonstration programme apart from the generating plant itself was expected to be the pilot fuel manufacturing plant expected to be built at Pelindaba. In 1999, Nicholls estimated this would cost about US$100m (R600m). A review of the project was begun by the government in January 2004 and it gave PBMR (Pty) Ltd 'two months to propose a way forward for the PBMR.'[20] The Demonstration Phase was then projected to cost US$1.3bn (R8bn) and it was still hoped to begin site work at the Demonstration Plant in 2004. In March 2004, Terblanche estimated the cost of the Demonstration Plant would be R10bn and it could not be in full operation before 2010, implying a 2007 construction start and the launching of commercial sales after 2012.[21] Ferreira[22] broadly confirmed these figures in September 2004.

[13] Nucleonics Week, October 14, 1999, p 7.
[14] Nuclear News, September 2001, p 35.
[15] Nucleonics Week, October 11, 2001, p 1.
[16] Nucleonics Week, April 18, 2002, p 1.
[17] Nucleonics Week, May 2, 2002, p 10.
[18] Nucleonics Week, December 19, 2002, p 1.
[19] Nucleonics Week, July 3, 2003, p 1.
[20] Nucleonics Week, September 2, 2004, p 5.
[21] Financial Mail, March 26, 2004, p 14.

However, in August 2005 Ferreira confirmed that the estimated cost of the demonstration phase had increased again to R14.5bn.[23] In November 2005, Kriek, addressing the South African Parliamentary Environmental Affairs and Tourism Portfolio Committee for the first time, gave a break-down of the constituent elements of the R14.5bn the demonstration phase is forecast to cost. R2bn was for the demonstration reactor, R4.5bn was for inflation and contingencies, R1.5bn was for the pilot fuel plant and R3.5bn was for the commercial fuel plant, and its design. The remaining R3bn were implicitly to pay the running costs for the PBMR Co. For such a risky and radical project, a contingency allowance of 45 per cent is not unreasonable, but, more correctly, the contingencies should be applied to the individual elements of the project giving a breakdown (if the contingency is spread evenly) of R2.9bn for the demonstration plant, R2.2bn for the pilot fuel plant, R5.1bn for the commercial fuel plant and R4.3bn for overheads. The figure for overheads seems unduly high and it is likely that a significant proportion of this cost should be allocated to the individual elements of the demonstration phase.

It is not clear whether the increase in the estimated cost of the demonstration in less than two years from R8bn to R14.5bn is accounted for mainly by the addition of the commercial fuel plant. Including the cost of a commercial facility, the commercial fuel plant, in the demonstration phase is totally inappropriate. There would seem to be little point in building a pilot fuel plant that did not produce enough fuel to supply the demonstration plant. The forecast cost of the demonstration phase should more correctly be R9.6bn with commercial orders for PBMRs paying for the commercial fuel plant, which not be built before it is clear that commercial orders will be placed.

In the period 1999-2005, the estimated cost of the demonstration programme appears to have escalated by a factor of more than seven. Some of this is due to the inappropriate addition of the commercial fuel plant, but the demonstration unit itself. The estimated cost of the demonstration plant itself has increased by about 50 per cent, the cost of the pilot fuel plant has increased by a factor of nearly four. The overheads appear not to have been estimated in the 1999 forecasts.

Until the detailed design is completed: equipment design development, for example on the turbine, has been carried out; design approval by the National Nuclear Regulator (NNR) is given; and the plant has actually been built, the cost estimates must be treated with scepticism. Experience with other nuclear projects shows these processes provide ample scope for further major cost escalation.

In 2005, a source close to the PBMR project forecast that the price of commercial units would now be R1.5bn, equivalent to about US$1500/kW, an increase in cost of about 50 per cent over the 1999 forecasts.[24]

2.3.3. The cost of capital

While the construction cost of the plant has been of continual concern, there has been little debate about the cost of capital. Traditionally, the cost of capital for power plants was very low, typically a real annual rate of 5-8 per cent. This low cost of capital reflected the fact that, as monopolies, electric utilities were generally able to pass on whatever costs they incurred to consumers, so there was very little risk that the loan would not be repaid. Of course, this did not mean that the risk of constructing new power plants was low, it simply meant that electricity consumers were bearing the risk rather than the company building the plant. Also government-owned utilities were regarded as being fully underwritten by government and the credit rating of government owned utilities was generally very high and the cost of borrowing correspondingly low.

In the past decade, with the opening up worldwide of the electricity industry to competition and the privatisation, at least in part, of many utilities, the position has changed dramatically. Many electric utilities, the potential customers for the PBMR, have been privatised and wholesale electricity markets introduced. This is planned to take place in South Africa with the splitting up of Eskom into regional distribution companies, a transmission company and a requirement to sell 30 per cent of its generation. This plan, notably the sell off of generation, appeared to be under review in October 2004 and it may be that Eskom will continue to be able to pass on the costs of its investments to consumers no matter how ill-conceived these decisions turn out to be. However, this is not a situation NERSA should tolerate.

However, in other markets, investment in generating plants is now a high risk to the owners and to the companies providing them with finance. The privatised utilities can no longer rely on government backing to support their credit rating. In Britain, the country that pioneered electricity privatisation and opening to

[22] Nucleonics Week, September 2, 2004, p 5.
[23] Business Day, August 16, 2005, p 2.
[24] K Kemm (2005) 'Local nuclear reactor to dominate world stage' Business Day, December 5, 2005, p 13.

competition of electric utilities, this risk is very real. In 2003, about 40 per cent of Britain's generating capacity was owned by financially distressed companies.[25] Half of this capacity was the nuclear plants while the rest was a mixture of coal and gas-fired plants. At one point, the second largest owner of power plants in Britain was the consortium of banks that had lent money to investors and had repossessed the plants when they began to lose money.

The experience with Britain's nuclear plants is particularly salutary. In 1996, the eight more modern nuclear power plants were privatised in a new company, British Energy. The sale proceeds were only about £2bn despite the fact that the plants sold included the Sizewell B plant, completed a year earlier at a cost to electricity consumers in excess of £3bn. Essentially, nuclear plants with a replacement value of at least £15bn, had to be given away in order for them to be saleable. Despite this, British Energy collapsed in 2002 and had to be rescued by the British government, which assumed liabilities, clearly to be paid by future tax-payers, with a value in excess of £12bn.[26]

Even before this stark demonstration of the economic risk of owning power plants, the real annual cost of capital for new generation plants in Britain was in excess of 15 per cent compared to about 6-7 per cent for investment in the parts of the industry that remained a regulated monopoly (essentially the distribution and transmission networks). In developing countries where currencies are less stable, there would be an additional risk premium on capital and, for example, the real cost of capital in Brazil would be at least 20 per cent. Given that repaying the capital charges is the largest element of the cost of nuclear power, it is easy to see if this cost is increased by a factor of 2-3, the impact on the economics of nuclear is going to significant and probably disastrous.

Nicholls (Nicholls, 2000) used a real cost of capital of 6 per cent and although this appears to have been increased to 8 per cent for subsequent analyses, this is far below the level that will be applied in many of the PBMR's target markets.

A decision to allow use of too low real cost of capital would have significant consequences, especially in a country like South Africa that has limited access to capital and very heavy demands for public spending in areas such as health and education where the returns on investment would be high and the risks low. Using capital on a low-return, high-risk project like the PBMR would risk crowding out more attractive and socially useful projects.

2.3.4. Maximum electrical output

There has been considerable confusion about the output of the Demonstration Plant, which has been variously reported as 110MW, 125MW, 137MW and 165MW. The DFR (PBMR, 2002a, p 25) stated the Demonstration Plant would be 110MW but would be modified in service to produce 125MW. The extent of the modifications necessary was not specified. It was implied that the first 10 commercial units would produce 125MW, but later units would produce 137MW. The DFR spoke of a later move to a core producing a thermal output of 400MW core and improvements in the conversion efficiency so that this would generate 200MW of electricity. The design changes necessary to achieve the 137MW output were expected to be such that earlier units could not be retrofitted to produce this higher level of output. In September 2003, Nicholls[27] was quoted as saying the Demonstration Plant would produce 125MW, while a year later, Nucleonics Week[28] reported 'the first unit would be limited to 110 MW'. In November 2004, Nucleonics Week[29] reported the thermal output of the plant would be 400MW, sufficient to generate 165MW. It reported: 'Eskom will file for revision of the EIA to take account of the higher electrical capacity' after final Record of Decision (ROD) was given. Since then, PBMR (Pty) Ltd has decided that the output of demonstration plant would be 165MW.[30]

[25] S D Thomas (2004) 'Evaluating the British model of electricity deregulation' Annals of Public and Cooperative Economics' 75, 3, 367-398.
[26] See European Commission (2005) 'Commission Decision of 22 September 2004 on the State aid which the United Kingdom is planning to implement for British Energy plc' Official Journal of the European Union', L142/46, European Commission, Luxembourg.
(http://europa.eu.int/eur-lex/lex/LexUriServ/site/en/oj/2005/l_142/l_14220050606en00260080.pdf)
[27] Nucleonics Week, September 25, 2003, p 10.
[28] Nucleonics Week, October 7, 2004, p 3.
[29] Nucleonics Week, November 4, 2004, p 1.
[30] Nucleonics Week, October 5, 2005, p 1.

2.3.5. Operating performance

For any technology with high capital costs, operating reliability is essential for good economic performance. To illustrate this, let us assume that the load factor[31] of a nuclear plant is expected to be 90 per cent and at this level, fixed costs will represent two thirds of the overall cost of power per kWh. If load factor is actually 60 per cent, this alone will raise the overall kWh cost by a third. Extra repair and maintenance costs to reflect the issues that produced this poor performance will increase costs even more.

Reliability of nuclear power plants worldwide has been extremely variable and has generally been well below the levels forecast. For example, the Dungeness B nuclear power plant in Britain, which was selected ahead of other options partly on the basis that it would have a high lifetime load factor of 85 per cent has, after 20 years of operation, a lifetime load factor of only 36 per cent. The two existing Koeberg PWR units, also after nearly 20 years of operation, have lifetime load factors of only about 65 per cent.[32]

Nicholls[33] forecast that the lifetime load factor of the PBMR would be 94 per cent. This is hard to justify. It would make the PBMR more reliable than any operating reactor worldwide. In 2004, the best lifetime load factor for any nuclear plant was 93.5 per cent and only 6 out of more than 400 operating units had achieved a lifetime load factor over 90 per cent.

For the Demonstration Plant, it might be expected that reliability would be poorer than for commercial units partly because of the need to carry out testing and demonstration activities, and partly because the Demonstration Plant will inevitably throw up technical problems that will only become apparent when a real plant is actually operated, and these will require shutdown for repair. If operating performance is expected to be significantly poorer than for the commercial units, this will make the power from the Demonstration Plant very expensive because the fixed costs will be spread over fewer saleable units of electrical output.

2.3.6. Operations & maintenance cost

There is a common perception that once a nuclear power plant is built, the electricity is essentially free. While fuel costs are generally low, operations & maintenance (O&M) costs can be high. For example, a number of US nuclear power plants were closed down in the 1990s because it was judged it would be cheaper to pay the cost of building and operating a new gas-fired plant than paying the cost of simply operating an existing nuclear plant. In the UK, British Energy collapsed in 2002 because income from sales of electricity was not sufficient to cover the operating cost of its plants. Intensive efforts have been made in the USA to reduce costs. The USA is the only country to publish properly accounted O&M costs. In 2003, the cheapest plant to operate generated at about US 1.2c/kWh (US cents) of which, about US 0.4c/kWh was fuel cost. The most expensive plant cost US 2.6c/kWh and the median was about US 1.65c/kWh.

No estimates of the operating cost of the PBMR have been published but Nicholls (Nicholls, 2000) estimated fuel costs at 0.4c/kWh, comparable to US figures. Given that in the same paper he forecast that total generating cost would be US 1.43c/kWh including repayment of capital, it is likely Nicholls assumes the non-fuel O&M costs will be negligible. The non-fuel O&M costs alone for US plants average about US 1.2c/kWh, so this assumption is highly optimistic and cannot be accepted without detailed justification.

2.3.7. Decommissioning cost

Decommissioning is an immensely complex area that cannot be fully covered here. If the South African government allows the PBMR project to proceed to the demonstration phase, it is important to note that this commits it not just to the cost of the facilities required, but also to pay for the decommissioning of the Demonstration Plant and other associated facilities such as the fuel manufacturing plant.

The DFR (PBMR, 2002a, p 27) anticipates two possible strategies, early plant dismantling or ‘safe enclosure’, in which stages 2 and 3 would be delayed. The DFR does not specify the length of the delay, but it should be noted that the THTR plant in Germany is expected to be in safe enclosure for at least 30 years. The DFR states that: ‘if the demonstration module is not successful, the plant will be mothballed in ‘safestore’ until the decommissioning of Koeberg I and II. However, negotiations with Eskom in this regard have not been finalized.’

[31] Load factor is calculated as the saleable electrical output of a plant in a given period (usually a year, or over its lifetime) as a percentage of the output it would have produced had it operated at its full design output rating uninterrupted.
[32] See Nuclear Engineering International, August 2004, p 38.
[33] Nucleonics Week, November 19, 1998, p 1.

Typically, it is assumed that the cost of decommissioning represents about a third of the construction cost. Since the decommissioning cost clearly has little direct relation to the construction cost, this indicates the immaturity of decommissioning technology and the only plants fully decommissioned worldwide are not representative. For example, they may have operated for only a short time and are little contaminated, or the plant may have been disposed of in a large hole without dismantling (Trojan, USA) or the plant is very small.

Experience with the plants of similar technology to the PBMR in Germany is particularly salutary. The pilot AVR plant (it produced 15MW of thermal energy but there was no turbine generator to convert the heat into power) is of similar technology to the PBMR and operated from 1967-88 before engineering problems caused its closure. The estimated cost of decommissioning and dismantling the AVR escalated from about €20-million during the early 1990s to as much as €490-million in 2002 (about R7bn).[34] So even after closure of the plant, decommissioning costs were subject to huge price escalation and if any provisions had been collected, they would have proved totally inadequate, leaving later generations to meet the cost.

The THTR 300 demonstration plant (which produced 300MW of electrical output), also using pebble bed technology, was in service for only six years to 1989 but produced minimal amounts of power and is therefore likely to be lightly contaminated. It was de-fuelled only in 1995, placed in 'safe enclosure' in 1997 and it is not expected that decommissioning of the contaminated parts of the plant will start before about 2020. No recent cost estimates for decommissioning have been published. If it had been assumed the plant would operate for 20 years and decommissioning provisions had been collected from electricity consumers on that assumption, any provisions would have been totally inadequate.

For a demonstration plant, which inevitably has a very uncertain length of operating life, it would seem more prudent to include the necessary provisions in the initial cost to reduce the risk of a shortfall in decommissioning funds if the plant operates for a shorter period than expected. No estimates exist for the cost of decommissioning the demonstration plant or the pilot fuel plant, but in view of the very high costs incurred for similar plants in Germany, it would be prudent, at least as a starting point, to assume that decommissioning these facilities will cost in the order R2bn and that this cost could fall in whole or in part on electricity consumers

2.3.8. Operating life

The expected operating life of the plant will determine how long the owner has to repay the construction costs. The longer the life, the lower the annual repayments are. In practice, expected operating life is not as important as might be expected. Generally, commercial loans do not have a repayment period longer than 20 years so this is the maximum 'amortisation' period for a commercial facility. Nicholls (Nicholls, 2000) projected a 40-year life for a commercial PBMR module. This would appear to be rather optimistic. No estimate has been given for the Demonstration Plant's lifetime. Demonstration plants often have quite a short life because they tend to be expensive to operate and once they have demonstrated (or failed to demonstrate as in the case of THTR 300) the technology, they are retired to reduce the losses consumers must bear. This is of particular concern if the decommissioning provisions are collected over the forecast operating life of the plant and this forecast proves too long.

2.4. Economics of the commercial units

Construction of the Demonstration Plant only makes sense if there is a high probability that it will lead to a profitable stream of orders for commercial PBMRs. It is therefore essential to examine the prospects for such sales if the economic case for the Demonstration Plant is to be properly assessed.

A key assumption is the construction cost. Let us assume the Demonstration Plant (not including the fuel plant) will cost about R3bn or about US$2,900/kW. The gap to commercial units costing R1.5bn is huge. Some of this cost reduction will come from not having to incur the technology start-up costs the Demonstration Plant would require. The rest must come from various scale economies and learning effects. These include: building ten units on a site; scale economies in manufacturing if a minimum number of units are sold. The DFR did not publish any details of these scale economies claiming the information was commercially confidential (PBMR (Pty) Ltd, 2002a, p 56).

2.4.1. The likely world market for the PBMR

PBMR (Pty) Ltd and Eskom have always been very vague about target markets and countries as wide-ranging as Chile, Cyprus, Turkey, Saudi Arabia and Egypt have all been mentioned as possible targets. There

[34] Nucleonics Week, July 18, 2002, p 2.

appears to be little basis for this speculation and these markets should be discounted until there is some substantive evidence to back them up.

The DFR (PBMR (Pty) Ltd, 2002a, p 50) is ludicrously over-optimistic, given the absence of anything remotely close to a firm order, suggesting that: 'the sale of PBMR plants and fuel is more likely to be constrained by supply capacity limitations than by demand.' It backs this up saying:

> The market analysis shows that the potential exists for the market to conservatively absorb up to 235 five-pack plants (1 175 modules) over the two decades following the start-up of the demonstration plant. This represents only 3.3 per cent of the world demand for new generation capacity. Notwithstanding this excellent potential, the base-case sales scenario adopted in the enterprise business plan forecasts the sale of only 258 modules over the evaluation period of 25 years, and is therefore conservative.

Given that over the past decade, the volume of nuclear plant ordered has been only one or two 1000MW units a year, this is far from conservative. It is clear that PBMR (Pty) Ltd has carried out no detailed market analysis on a country-by-country basis and projections are simply an arbitrary percentage of an overall market for power plants. This issue was raised by LRC as Comments on the DFR (Register of Comments, 2002, 28.137) but the response does not make much sense and does not answer the question. It states;

> The market studies were based on 53 plants, only one of which is to be sold to Eskom. Thorough market studies were done as part of the business case. We are not sure on what the statement "it seems likely that the world market for nuclear power may be no more than 1 or 2 units per year" is based, especially since the world market for new power stations is about $70 million per year.

No mention is made elsewhere of 'the market studies of 53 plants'. Since $70 million would only, on PBMR (Pty) Ltd's figures, cover about half the cost of one PBMR module, it is not clear what the response means.

The fact that a large percentage of the market is effectively closed to nuclear power by political decision is not taken into account. Even so, it should be noted the DFR represents a significant downgrading of sales forecasts to about 10 units a year from earlier when Nicholls (Nicholls, 2000) forecast 30 units per year. This weakness was acknowledged by the new CEO of PBMR (Pty) Ltd in September 2004 when he said there was a need for 'a "much more detailed marketing strategy" with "a strong focus on customers' needs. He said marketing strategies would be tailored to a given country or customer, versus a more generic strategy followed in the past.'[35]

Such studies would quickly reveal that for much of the world, new orders for nuclear plants are not feasible. In Europe, many countries have made a decision not to build nuclear power plants, e.g., Austria, Denmark, and Norway or are phasing out nuclear power, e.g., Germany, Italy, Sweden, Belgium the Netherlands and Switzerland or not expanding existing capacity, e.g., Spain. The UK government is now reconsidering nuclear power, but it is likely that any orders placed would be for Westinghouse's AP-1000 model. France decided in November 2004 to build a new nuclear power plant of a French design, EPR, a 1500MW design based PWR technology, and it is highly unlikely it would abandon this in favour of the PBMR. The medium-term prospects for PBMR sales in Europe therefore appear minimal.

In the USA, PBMR (Pty) Ltd's hopes were based on Exelon getting license approval for the PBMR and launching the commercial programme ordering 10 units. This will not happen now and while some utilities offer supportive statements to the technology, as expressions of intent to buy plants, these are worthless. Under the US government's Nuclear Power 2010 programme, a number of utilities have expressed an interest to build new nuclear plants, using government subsidies, but none is planning to order PBMRs.

Whether the US government initiative will lead to new orders for any type of reactor remains to be seen. The CEO of Dominion, one of the leading US utilities apparently bidding for government money said: [36]

> "We aren't going to build a nuclear plant anytime soon. Standard & Poor's and Moody's would have a heart attack," said Mr. Capps referring to the debt-rating agencies. "And my chief financial officer would, too."

The main expected export market therefore appears to be China, but despite several years of discussions, China has made no commitment to South African PBMR technology. Tsinghua University has the only operating PBMR in the world, a 10MW unit that went critical in 2000 using German fuel technology. Tsinghua University is collaborating with US interests from the Massachusetts Institute of Technology on a

[35] Nucleonics Week, September 2, 2004, p 5.
[36] M Wald (2005) 'Interest in Reactors Builds, But Industry Is Still Cautious' New York Times, April 30, 2005, p 19.

competitor to the South African PBMR.[37] Overall it is far from clear who Chinese companies will choose to collaborate with, but all experience shows that Chinese interests will try to 'indigenise' any technology they pursue so even if they do collaborate with PBMR (Pty) Ltd, and orders are placed, South African content to these sales would low and the net benefit of these sales to South Africa small.

It is more likely that China will produce its own design of PBMR, similar to that of PBMR (Pty) Ltd, which would supply any sales in China and compete with South Africa in world markets. Nucleonics Week reported in June 2005 that Tsinghua University's Institute for Nuclear & New Energy Technology (INET) expected to complete the design for a commercial scale of plant (about 195MW) by 2006 and have a plant in operation by 2010.[38] These forecasts may be no more realistic than those of its South African counterpart but the intention to develop an independent design rather than import technology is clear.

If a world market for high temperature gas-cooled reactors does develop, as well as competition from a Chinese vendor, the South African PBMR may face competition in international markets from the US vendor General Atomics and from Areva, companies that are both developing designs using prismatic fuel. General Atomics supplied the demonstration HTGR built in the USA (Fort St Vrain) and has the advantage of being US-based and therefore politically well-placed to receive US government funds. Areva has less experience with HTGRs but its huge experience in reactor design and sales gives it advantages in international markets.

A pre-condition for any international sales appears to be obtaining safety approval from the US NRC. Without a US partner and with no sales in prospect, it is not clear why the USA should spend US taxpayers' money reviewing the PBMR design. If PBMR (Pty) Ltd is to obtain licensing approval in the USA, a large proportion of the cost will therefore have to be borne by PBMR (Pty) Ltd.

2.4.2. The South African market for PBMRs

In the absence of foreign markets, Eskom is the most likely customer. Eskom has committed to build and operate the Demonstration Plant. It has said it will buy 10 units, but only 'provided it's the lowest-cost alternative at the time the utility needs to add capacity'.[39] Eskom does not say in the FEIR whether, on current expectations of cost of a commercial unit it expects the condition that it be the 'lowest-cost alternative' to be met. In the second half of 2004, pressure on Eskom to commit unconditionally to buy several commercial units increased. In October 2004, Kriek said the PBMR (Pty) Ltd's business plan 'envisages Eskom committing up front to some 4,000 MW of PBMR capacity in South Africa, which would allow "economies of scale" and development of a commercially competitive product.'[40] This plan appeared to be endorsed by the government Minister for Public Enterprises, Alec Erwin, in his mid-term budget statement of November 26, 2004, when he said: 'plans include the additional generation of 4,000MW to 5,000MW of electricity from pebble bed units located around the country.' Tom Ferreira, communications manager for PBMR, said that around 4,000MW of electricity could be met by 24 PBMR units each with a generating capacity of 165MW. If the cost of these units was R1.5bn each, this would mean that Eskom was being asked to commit to making an investment of at least R36bn before the technology was economically or technologically proven. As with the demonstration plant, buying these units also commits consumers to pay for the decommissioning of these units. There is no basis for forecasting this cost, but experience elsewhere suggests the cost could easily in the order of tens of billion Rand.

However, the signs are that Eskom wishes to distance itself from the project. The forecast time when new generating plant will be urgently needed is difficult to predict because of uncertainties about demand growth rates, the degree to which old plants can be refurbished and mothballed units returned to service. Steve Lennon, Eskom's MD for resources and strategy suggested that 1000MW of new peaking capacity (power plant required for times of peak demand) would be needed each year from 2005-09 with base-load capacity (power stations that operate throughout the year) needed from 2010 onwards.[41] Clearly the PBMR, which cannot be in service as a commercial option before 2013[42] at the earliest, is of little relevance to this immediate need for new capacity.

[37] Nucleonics Week, November 6, 2003, p 1.
[38] Nucleonics Week, June 23, 2005, p 8.
[39] Nucleonics Week, August 28, 2003, p 1.
[40] Nucleonics Week, October 7, 2004, p 3.
[41] Financial Mail, December 10, 2004, p 36.
[42] The Energy Minister, Phumzile Mlambo-Ngcuka said in August 2004 that 'the pebble-bed modular reactor was at least 10 years away from becoming a commercially viable project'. Business day, August 16, 2004, p 2.

The managerial changes in PBMR (Pty) Ltd in August 2004 when an IDC executive, Jaco Kriek, became CEO and a Department of Trade & Industry Director-General, Alastair Ruiters became Chairman, replacing the predecessor from Eskom, Nic Terblanche were reported as being 'intended to get the project out from under the management of South African utility Eskom**,** which does not want to be in the business of developing new nuclear technology.'[43] This echoes the position taken by Exelon in 2002 when they withdrew. These changes seem to be supported by the government. Nucleonics Week[44] reported:

> Up to now, the chairman of Eskom Enterprises, Eskom's subsidiary for unregulated industry, has automatically held the PBMR chairmanship, but now it's not even certain that Eskom will be represented on the board. An informed source said the government is "not eager for Eskom to continue as an investor and a potential customer," in part because that would inevitably lead to conflict-of-interest situations.

The CEO of Eskom confirmed this interpretation in evidence to the South African Parliament Portfolio Committee on Minerals and Energy. Eskom would be "playing a lesser role (as a PBMR investor) as we go forward, because we are now going to take the role of customer".[45] He said that the PBMR should not go forward without foreign investors. He said more international investors were needed "to be able to advance to the stage where we can construct the demonstration unit and have it commercially proven" and that Eskom would "dilute" its participation as an investor in the PBMR, and allow other investors to be brought in. He also seemed to confirm that PBMR would have to be the cheapest option if Eskom was to buy it: 'if all of our technical and commercial criteria are met, we'll be taking the first set of units that are produced.'[46]

The South African government affirmed in October 2004 its commitment to open up the electricity generation sector to foreign investment. The Trade & Industry Minister, Alec Erwin[47], suggested that about a quarter of the investment needed up to 2009 would come from companies other than Eskom. This effectively removes from Eskom the obligation to ensure there is sufficient generating capacity for the country. It also in effect places Eskom in a competitive market. In this situation, it would be unreasonable to expect Eskom to compete with new generators if it was obliged to buy a number, specified by the government, of PBMRs regardless of whether they were the cheapest option or whether they were even required. The only logical commitment Eskom can be asked to make is that it orders PBMRs when it needs new capacity, provided it is the cheapest option available. In practice, this is a largely empty commitment because, if when it needed new capacity the PBMR was the cheapest option, it is hard to see why Eskom would not order it.

[43] Nucleonics Week, August 26, 2004, p 7.
[44] Nucleonics Week, September 2, 2004, p 5.
[45] Sunday Times, November 10, 2004.
[46] Sunday Times, November 10, 2004.
[47] Business Day, October 27, p 2.

PART 2 Implications for the NER/NERSA

3. The Risks

The programme to develop the PBMR in South Africa has been under way in earnest since 1998. Costs have escalated and schedules have slipped dramatically since then with the time when the first commercial units would come on-line now expected no earlier than 2013 compared to 2004 in 1998. The expected cost of the feasibility phase of the PBMR programme has also increased by a factor of about seven. The next 5-10 years could see a need for investments in excess of R50bn, much of which could fall on electricity consumers.

The PBMR was conceived mainly as an export product. If the project is successful, the main beneficiaries, on current share-holdings, will be the South African government, which is expected to be the largest shareholder although PBMR (Pty) Ltd, the company set up by Eskom to develop the technology has said it expects to attract additional private sector investors. If new investors are brought in, these will also benefit.

The project is widely acknowledged to be an economically high-risk project[48] and, especially given that they will not be the main beneficiaries if the project is successful, it is inappropriate for electricity consumers to be asked to bear this risk. At one end of the economic spectrum, some electricity consumers are the poorest members of society who struggle to afford even the minimum electricity requirements and at the other end, others are South Africa's electric intensive industry, which depends on the availability of cheap, reliable electricity supplies for its international competitiveness. Such consumers can ill afford to take a gamble on the price of electricity. NER, and its successor NERSA, is the national regulatory body whose job it is to approve consumer tariffs and it is therefore the body that must bear responsibility for ensuring that electricity consumers are not subject to this risk.

Eskom's direct interest in the PBMR venture is through its 'Enterprises' division, which is a shareholder in the company set up to develop the technology, PBMR (Pty) Ltd. Consumers could be subject to risk from the PBMR project in four main ways:

1. Eskom Enterprises is committed to provide 52.5 per cent of the feasibility phase of the PBMR development programme, which started in 1998 and appears to have cost in excess of R1.5bn, so Eskom Enterprises appear to have invested or expect to invest about R800m. The lack of a clear corporate separation between the divisions of Eskom since the re-absorption of Eskom Enterprises into Eskom in 2005 leads to a risk that this cost could be passed on to consumers if the project fails;
2. Eskom expects to retain at least a 5 per cent share of the project in the next stage of development, the 'demonstration phase'. This phase is expected to cost at least R14.5bn, making the Eskom Enterprises share a further R725m. However, a large part of the investment need is still unallocated and Eskom could be called on by government to increase its share to 40 per cent or more, equivalent to about R6bn. As in the first case, there is a risk that this cost could be passed on to consumers if the project fails;
3. Eskom Generation is committed to buy the Demonstration Plant on 'normal commercial terms'. It is not clear what is meant by 'normal commercial terms', but the plant is expected to cost at about R3bn and will not be the cheapest source of new capacity available to Eskom. The cost of decommissioning must be added to this, perhaps of the order R2bn. Consumers could be asked to pay the extra costs arising from the Demonstration Plant if Eskom agrees to pay more than the cost of the cheapest option;
4. The South African government expects Eskom to order 24 commercial units in 2009. The projected price for these plants is at least R1.5bn each, making a total investment of at least R36bn. To this must be added the cost of decommissioning these plants, a cost likely to be in the order of tens of billion Rand. Consumers could be asked to pay the extra costs if the commercial units prove not to be the cheapest option available to Eskom.

It is possible that Eskom could be committed to invest more than R40bn on the PBMR programme, about R1000 for every citizen of South Africa, before the Demonstration Plant has even entered service. If the plants prove to be expensive to operate, consumers could face increased electricity bills throughout the lifetime of the plants, expected to be about 40 years. To put this in context, if we assume that 25 PBMRs are

[48] The Chief Executive Officer of Pebble-Bed Modular Reactor Limited, Johann Kriek, was reported as describing the PBMR project as 'high-risk' to the Environmental Affairs and Tourism Portfolio Committee on 8 November 2005. Business Day, November 9, 2005, p 2.

built and even if they only 1c/kWh more to operate than the cheapest option, this would lead to extra costs over a 40 year plant life of R10bn. To this would then be added the high cost of decommissioning the plants.

4. Investments by Eskom Enterprises

The first two costs risks arise through the involvement of Eskom Enterprises and depend on the extent to which losses in Eskom Enterprises could fall on electricity consumers.

4.1. The status of Eskom Enterprises

In Eskom's 2005 Annual report, Eskom Enterprises was listed as one of four subsidiaries of Eskom and was a legally separate company. The Eskom Annual Report stated:

> Eskom Enterprises, a company domiciled in South Africa, was registered to accommodate all the non-regulated energy-related activities of Eskom in South Africa and its energy-related activities outside South Africa.

However in 2003 and 2004, it had to essentially write off two of its major investments, in the Second National Operator (telecoms) and Mountain Communications (Pty) Limited (MKC), resulting in losses of over R1bn. A 'revised business model' was imposed by government and Eskom reported:

> As a direct result of the revised business model, we reviewed the strategic fit of our line divisions and subsidiaries. Eskom Enterprises was transformed into Enterprises Division and given a new revised mandate to project manage and build the new capacity. This has freed and enabled line divisions to concentrate on the day-to-day business of managing the generation, transporting, trading and retailing of electricity. Line divisions become the new clients of the Enterprises Division, while each division retains a unique strategic capability not duplicated elsewhere, with the Executive Committee integrating the functions at the highest level.[49]

Essentially, Eskom Enterprises has been re-absorbed back into Eskom along with its entire staff and any legal distinction between Eskom and Eskom Enterprises has gone. For the purposes of regulation, it is not clear whether NER requires separate accounts for the Enterprises division but if the investment to date in the feasibility phase is lost, there need to be clear measures in place to ensure that these losses are not passed on in some form to electricity consumers. There is an urgent need for NERSA to clarify how it intends to ensure that consumers are not liable for any of the costs incurred by Eskom in the feasibility phase. NER has not been able to scrutinise fully Eskom's projected costs and investments over the period to March 31 2009, but it should seek assurances from Eskom that no costs associated with the PBMR will be passed on to consumers, with the threat that if it emerges that costs have been passed on, they will be 'clawed back' from Eskom through lower prices and hence lower profits.

4.2. The feasibility phase

The PBMR was developed within Eskom until June 2000. Then British Nuclear Fuels Limited (BNFL) took a 22.5 per cent stake in the venture followed by the US electric utility, Exelon (12.5 per cent). The government-owned Industrial Development Corporation (IDC) took 25 per cent of the venture subsequently reduced to 12.5 per cent, leaving 52.5 per cent with Eskom.

Exelon left the project in April 2002 but fulfilled their commitment to fund the feasibility phase. No authoritative figure of the cost of the feasibility phase has yet been published, nor even has it been stated that the feasibility phase is complete and the demonstration phase has started. Let us assume that: the feasibility phase ended at the end of 2004[50] and expenditure in the remaining months of 2004 was about R50m per month[51] making a total of R1.75bn; IDC, Exelon and BNFL paid their full 12.5, 22.5 per cent and 12.5 per cent contributions; and Eskom Enterprises paid the balance (52.5 per cent) of the costs. This would mean that Eskom Enterprises would be contractually liable for a little more than R900m.

It is not clear whether partners that did not take up their shareholding in the reconstituted company (or reduced their shareholding) would be able to recover their share of the development costs, for example, by selling their rights to a third party. Eskom has stated it expects to reduce its contribution to the demonstration phase to 5 per cent.[52] If no reactors are sold, the money Eskom Enterprises invested in the feasibility phase will be lost and unless it can sell on its rights to shares in the demonstration phase company, nearly all its

[49] Eskom (2005) Annual Report, p 78.
[50] In 2003, it was reported that the feasibility phase was close to completion. Business Day, May 20, 2003, p 18.
[51] Nucleonics Week, August 28, 2003, p 1.
[52] Nucleonics Week, September 1, 2005, p 1.

investment will be lost. At best, it might begin to recover some of this money from 2011 onwards when it is hoped commercial plants can start to be ordered. So clearly, the money Eskom Enterprises has invested so far, apparently about R900m, is at risk. The issue for consumers is how strong is the separation between Eskom Enterprises and the divisions of Eskom that are involved in the supply of electricity to consumers now that the legal distinction between Eskom and Eskom Enterprises has been removed.

4.3. The demonstration phase

Eskom has been trying to find ways of reducing its holding in the project since 2003 and it is now hoping to take no more than 5 per cent of the demonstration phase company. The other investors are expected to be IDC (14 per cent), BNFL (15 per cent) and the South African government (30 per cent).[53] Even if these three holdings are taken up in full, that leaves 36 per cent of the shares still not taken up. PBMR (Pty) Ltd has been quoted on numerous occasions in the nearly four years since the withdrawal of Exelon as expecting new (foreign) investors to take a share of the new company, but these new partners have not yet materialised. In addition, of the three other investors, only the government stake looks reasonably secure. It is not clear why IDC, having reduced its stake from 25 per cent to 12.5 per cent in the feasibility phase would now want to increase its stake in the much more expensive demonstration phase. BNFL is in the process of being broken up with most of its businesses expected to have been taken away from it by the end of 2006. The Westinghouse division, the division that is participating in PBMR development, is being privatised.[54] Whether the BNFL stake is actually carried through will be a decision that will be taken by the new owners, not the current management.

If there are insufficient investors, there is a risk that government will require Eskom to increase its holding from 5 per cent. On current cost estimates, its 5 per cent stake equates to a commitment to R800m.[55] If the unallocated portion of the shares in PBMR (Pty) Ltd is not taken up or one of the partners withdraws or reduces its holding, Eskom might find itself obliged to take more than 50 per cent of the demonstration phase, a commitment of perhaps R8bn. There is an urgent need for NERSA to ensure that the risk of the investment by the Eskom Enterprises division in the demonstration phase is not passed on to consumers.

5. Purchase of PBMR units

The second two risks identified above - risk from purchasing the Demonstration Plant and risk from Eskom purchasing commercial units - are potentially much larger than the risks incurred to date by Eskom Enterprises, and fall on the Eskom Generation division. The extent to which any losses will be borne by electricity consumers will depend on NER's policy on regulation. To understand the nature of the risk requires a brief explanation of how electricity regulation is expected to be carried out in South Africa.

5.1. Regulation of the generation division

The 2006 multi-year price determination that will apply from April 1 2006 is the first 'multi-year price determination' (i.e., it will set electricity prices for several years forward) and is being done to a tight time-table. It is basically an interim review and NER expects that 'a full review will be planned starting in 2007 so that a robust independent view is available prior to the next multi-year control period due from 1 April 2009'[56] when a five year price determination is expected. NER acknowledges that the current price control is far from rigorous: 'the timetable for this multi-year period did not permit a full independent review of the plans and business of Generation or Distribution.' In short, a detailed review of Eskom's investment plans and its forecast operating costs, as would normally be required using the methodology NER has adopted, has not been carried out.

While the PBMR programme should have limited impact on the price determination from 2006 to 2009, the next determination could be heavily influenced by the impact of the proposed PBMR programme and if the NER's objectives, particularly 'consistency between controls' are to be met, it is important that early signals to Eskom on how PBMR investment will be treated should be given.

[53] Nucleonics Week, September 1, 2005, p 1.
[54] The short-listed bidders are two US companies, GE and Shaw, two Japanese companies, Mitsubishi and Toshiba.
[55] Nucleonics Week, September 1, 2005, p 1.
[56] NER (2005) 'Multi-year price determination of Eskom', NER, Pretoria, p 18. (http://www.ner.org.za/documents%5CPublic.pdf)

5.1.1. The methodology

NER is using a form of regulation modelled on the methods developed in Britain for its electricity industry over the past 15 years (Thomas, 2004). This uses a form of rate-of-return methodology and is based on the assumption that operators of a monopoly service should receive a 'fair' rate of return on the money they invest in return for providing a reliable supply of electricity. The industry is divided into three main parts for this purpose:

- The generation business: Operation of the power stations;
- Transmission: Operation of the national high voltage transmission network that takes power from the power stations to the demand centres; and
- Distribution and retail: Operation of the local and regional low voltage networks that take the power from the transmission grid to final consumers and purchasing electricity from generators and retailing it, including metering and billing, to final consumers.

Eskom's main divisions correspond to these three activities.[57]

The amount of revenue each division is allowed to earn from their charges is based on the formula:

Allowed income = (Value of assets – depreciation + new investment) * Fair rate of return + Operating costs

The allowed income streams for the three parts of the business, generation, transmission and distribution, are added together to give the total sum of money that Eskom will be allowed to recover from consumers from the sale of electricity. If this allowed income is spread over the forecast electricity demand, this allows the average change in the price of electricity supplied to be calculated. The term including value of assets, depreciation and new investment is known as the Regulated Asset Base (RAB).

For the purposes of the analysis of the possible impact of the PBMR programme, the generation division is the relevant one and the two key terms in the equation are 'new investment' and 'operating costs'. Generation accounts for about 52 per cent of the value of the assets of the three divisions at the start of the period (April 1 2006), and by March 31, 2009, generation assets account for 60 per cent of the total asset base, reflecting the heavy expenditure on new power plants Eskom expects to have to undertake. Generation also dominates operating costs, accounting for two thirds of the operating costs of the three divisions in 2006/2007, increasing somewhat to about 68 per cent by 2008/2009. The generation sector is therefore the dominant sector in determining the price paid by consumers for the supply of electricity.

5.1.2. Additions to the RAB

A key role for the regulator is determining what assets the regulated company should be allowed to add to its asset base. Clearly there is an incentive on utilities to invest as much as possible because the larger their investments, the more income they are allowed to make. This is often known as 'gold-plating'. US practice with rate-of-return regulation therefore requires that new assets should be 'used and useful' and the investment costs should have been 'prudently incurred'. Regulators review investments and if they are not 'prudent', the regulator may choose to disallow the investment from the asset base or only allow the 'prudent' part into the RAB. 'Imprudent' investments are therefore paid for from profits and their cost does not fall on consumers. NER follows these principles and states:

> In the second consultation paper the NER set out the principle regarding acceptance of capital expenditure into the Regulatory Asset Base: "it would be the NER's intention to include Eskom's capital expenditure into the RAB except to the extent that it is shown to have been incurred imprudently or improperly. The presence of incentives for efficiency and project delivery would be seen as reducing the risk of imprudent or improper expenditure."

5.1.3. Operating costs

In the form of rate-of-return regulation used by the NER, an *ex ante* form[58], the regulated company negotiates an allowed level of operating costs with the regulator. If the regulated company can operate the system for less than is forecast, it can keep the savings as extra profits. This provides an incentive to the

[57] In the future, the retail monopoly might be broken to allow consumers choice of supplier, in which case, the retail element would be separate from distribution and would be set by the market

[58] Under the UK and South African methodology, costs are estimated for a forward period, while in the USA, investments are only assessed for inclusion in the asset base after they have been completed. The risk with the UK method is that the regulator is effectively making investment decisions, while the risk with the US method is that companies will be inhibited from investing because of the risk that they will not be able to recover their costs.

company to improve its efficiency. However, it is also an incentive to over-estimate its likely costs and underestimate the extent of possible efficiency savings because higher than anticipated savings can be kept as extra profits. The regulator therefore has a heavy responsibility to ensure that the allowed operating costs require the regulated company to carry out all reasonable efficiency savings.

5.2. Purchase of the demonstration unit

Construction of the demonstration unit is expected to begin in 2007 with first power in 2010 and to be handed over to Eskom in 2011. The Demonstration Feasibility Report (PBMR, 2002a, p 32) states: 'Eskom will, upon successful commissioning, purchase it from PBMR (Pty) Ltd on normal commercial terms.' It is not clear what 'normal commercial terms' means. It could mean: paying the forecast cost of a commercial PBMR plant; paying the equivalent cost of the cheapest generating option; paying the full cost of the Demonstration Plant, minus some development costs and the cost of the fuel plant that is being built in the demonstration phase.'

Johan Kriek, the CEO of PBMR (Pty) Ltd, told the Environmental Affairs and Tourism Portfolio Committee on 8 November 2005 that the cost of Demonstration Plant would be about R3bn. Since the main benefit of the Demonstration Plant will be to demonstrate to potential customers the viability of the PBMR, this will be a benefit to PBMR (Pty) Ltd, not the Eskom Generation Division or its consumers. Consumers should be required to pay no more than if Eskom had bought the capacity provided by the Demonstration Plant using the cheapest overall generation option. To put this in perspective, a combined cycle gas turbine (CCGT) power plant, probably the cheapest option for increasing generating capacity, with the same output as the Demonstration Plant would cost about R500m. A new coal-fired plant with modern emissions controls would be significantly more expensive than a CCGT, but still much less than the PBMR Demonstration Plant.

While the construction cost of the Demonstration Plant is uncertain, the operating cost is even more uncertain and there appears to be no mechanism for Eskom to recover additional operating costs from PBMR (Pty) Ltd. Operating costs will be higher than the expected cost for commercial PBMRs because a small-scale prototype fuel plant will be used and because the Demonstration Plant is likely to be less reliable than follow-up commercial plants. PBMR (Pty) Ltd has not published its estimates of the expected operating cost of the Demonstration Plant. The operating costs of the cheapest alternatives, such as CCGT plants or new coal are well known by Eskom and can provide the reference point for calculating what operating costs for the Demonstration Plant it would be reasonable to pass on to consumers.

The cost of decommissioning the demonstration plant should not be ignored. This could be of the order R2bn. It is not clear whether this would be accounted for as an operating cost or as an additional capital charge. NER, and NERSA in subsequent price settings, should ensure that for the Demonstration Plant, the capital costs added to the RAB, the operating cost added to allowed operating costs and the decommissioning cost are no more than the equivalent of the cheapest option. If the generation division of Eskom pays more than these costs, it must come out of its profits.

5.3. Purchase of commercial units

In 2002, Eskom provided PBMR (Pty) Ltd with a letter of intent saying it would buy 10 commercial PBMR units, but only 'provided it's the lowest-cost alternative at the time the utility needs to add capacity'.[59] Misleadingly, PBMR (Pty) Ltd, in its Demonstration Feasibility Report (PBMR (Pty) Ltd, 2002, p 50) does not include this caveat on cost, saying only: 'Eskom has provided PBMR (Pty) Ltd with a letter of intent covering the purchase of a Demonstration Plant and 10 further units.' In practice, most letters of intent have little commercial force and do not commit the company to actually place any orders.

Following the withdrawal of Exelon and the failure to get replacement investors or PBMR orders, pressure has mounted on Eskom to firm up its commitment and increase the number of units it would buy. Exelon had pledged to buy 10 commercial units (not conditional on it being the cheapest option) including the first plants and suggested that it would buy 40 or more units in the first decade of the commercial phase.

Since 2004, there has been speculation that Eskom would be required to order about 24 commercial units in 2009, probably at a cost of R1.5bn each, a total of R36bn. The cost of decommissioning the plants at the end of their life must be added to this. In an article in the October 24 South African Sunday Times, the South African Minister of Public Enterprises, Alec Erwin stated that 'the plan is eventually to produce 4000-5000

[59] Nucleonics Week, August 28, 2003, p 1.

MWe of capacity from pebble bed reactors around the country.' Given that commercial units are expected to produce an output of 165 MW, this equates to 24-30 PBMRs. In an interview for Moneyweb (November 6, 2004), Johan Kriek, the CEO of PBMR (Pty) Ltd stated: 'As part of our new business case, we intend to sell 24 reactors to Eskom, and it makes sense because 24 is the economies of scale for your commercial fuel plant, the pebbles that you manufacture.' It has subsequently been reported that the orders should be placed in 2009, two years before the Demonstration Plant is expected to be handed over to Eskom.[60]

Being required to place 24 orders at a cost of R36bn a year before the Demonstration Plant is expected to be complete and two years before Eskom takes possession of it would be an extraordinary risk for Eskom. In 1998, Eskom stated: "It is considered that a proving period of up to three years would be required to validate the (PBMR's) competitive economics against Eskom's other low cost options." If plants are to be ordered a year before the demonstration plant is complete and with no time allowed to evaluate its performance in practice, it makes it difficult to understand what the function of the Demonstration Plant actually was.

The CEO of Eskom told the South African Parliament Portfolio Committee on Minerals and Energy 'if all of our technical and commercial criteria are met, we'll be taking the first set of units that are produced.'[61] This seems to confirm the earlier commitment that Eskom would only buy commercial units if they represent the cheapest generation option. NER and NERSA need to confirm this position with Eskom and should make it clear that it will only allow into the RAB and the allowed operating costs, the costs of the cheapest option. If Eskom chooses to buy power plants that do not provide the cheapest source of power, the additional costs should come out of its profits and not be recovered from consumers. If government requires Eskom to purchase PBMRs even though they are not the cheapest source of power, it should compensate Eskom for the extra costs imposed so that consumers are not being asked to pay for a government policy. There are clear precedents for such compensation. For example, in Britain, in 1972 and 1979, the government required the equivalent company to Eskom, the CEGB to place orders for an oil-fired power station (1972) and a coal-fired power station (1979). These decisions were to retain a capability in equipment manufacture.

6. Conclusions

There is a strong expectation from Eskom and the electricity regulator (NER) that electricity prices will have to rise over the next 15 years mainly to pay for the construction of new power stations to meet growing demand and to replace old worn-out stations. The NER and its successor, NERSA, will play a critical role in ensuring this investment need is met, but that the burden on consumers is not heavier than it need be.

The PBMR is expected to play a major role in this investment need, but the PBMR development programme, represents a major risk to electricity consumers. The PBMR programme is at a cross-road. Public expenditure to date has been high, but the next phases will require public expenditures, mainly financed by electricity consumers, of about 20 times the sums so far spent. Before commitment to these next phases are made, it is essential that NER understands the risks involved and makes clear to all concerned parties what its policy towards expenditure by Eskom on the PBMR will be.

In part, the risk is that Eskom will try to recover the costs it has put into the feasibility phase (about R900M) and from the demonstration phase (potentially in the order R8bn). The extent of the costs Eskom will incur in the demonstration phase are very uncertain, partly because there is still ample scope for costs to escalate and partly because it could be required to take a much larger stake in the PBMR company than it currently plans. The minimum investment appears to be R800m, but there is ample scope for the actual figure to be 10 times that. The part of Eskom involved, the Enterprises division, was formerly a legally separate company, but in 2004, it was re-absorbed back into the main company making it more difficult to ensure costs incurred by Enterprises remain isolated from electricity consumers.

NER Role. NER should take steps to ensure that the Eskom Enterprises division is fully financially separated from the regulated businesses, especially electricity generation, to ensure that the regulated businesses do not cross-subsidise the PBMR feasibility and demonstration phases.

The much larger risk to consumers arises from the commitment by Eskom to buy the Demonstration Plant at a cost of up to R3bn and the first 24 commercial units at a cost of up to R36bn. Buying these plants would also commit Eskom to pay for their decommissioning, a cost likely to be of the order of tens of billion Rand.

[60] Noseweek, December 2005.
[61] Sunday Times, November 10, 2004.

The Demonstration plant, by its nature, will not be an economic source of power and consumers should not be expected to subsidise development of the technology.

NER Role. For the demonstration PBMR plant, NER must ensure that only the cost of the cheapest generation option is allowed in to the Regulated Asset Base (RAB) of the Generation division when Eskom purchases the Demonstration Plant and that Eskom can only recover the operating costs of the cheapest generation option from its consumers.

It has been acknowledged by Eskom that the commercial PBMRs might not be the cheapest form of generation available to it and if this is the case, electricity consumers should not be asked to bear these additional costs

NER Role. For any commercial PBMRs orders, NER must make it clear to Eskom that it will only allow the construction cost of the cheapest generation option into the RAB and allow Eskom only to recover the operating costs of the cheapest generation option.

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Appendix CV: Stephen Thomas (Nuclear power & energy regulation research)

Recent projects and consultancy on nuclear power and electricity regulation

Commissioned (2004) by the South African Legal Resources Centre to submit evidence to the government's Environmental Impact Assessment for the proposed Pebble Bed Modular Reactor in South Africa.

Member of a team appointed by the Inter-American Development Bank to advise the Brazilian government on reform to their electricity industry (2003).

Consultant to the UK Environment Council (2004) to provide expert assistance to NGOs on financial aspects of decommissioning policy (as part of their participation in the Magnox Decommissioning Dialogue).

Consultant commissioned by the UK Environment Agency (2005) to write a report on the economics of nuclear power.

Member of expert panel (2005) to review the cost of wasted disposal options for the UK government's Committee on Radioactive Waste Management.

Member of team (2006) appointed by the European Commission to review decommissioning fund methodologies in the European Union

Official appointments related to nuclear power and electricity regulation

Member of the team appointed by the European Bank for Reconstruction and Development to carry out the official economic due diligence study for the project to replace the Chernobyl nuclear power plant (1997). Member of an international panel appointed by the South African Department of Minerals and Energy to carry out a study of the technical and economic viability of a new design of nuclear power plant, the Pebble Bed Modular Reactor (2001-02). Member of an independent team appointed by Eletronuclear (Brazil) to carry out an assessment of the economics of completing the Angra dos Reis 3 nuclear power plant (2002).

Research on nuclear power economics and policy, and on electricity regulation

Ongoing interest in the operating performance of nuclear power plant. Analysis of nuclear power policy in general. Research into the determinants of the economic performance of nuclear power plant, particularly the influence of institutional structure. In depth analysis of the French nuclear power programme. Appeared as expert witness at the Sizewell B (1983) and Hinkley Point C (1988) nuclear power plant public inquiries and submitted evidence to the Ontario Hydro Demand/Supply Plan Hearings (1992). Co-editor of two special issues of the journal Energy Policy (1992) which marked the 50th anniversary of the first nuclear chain reaction and of a special issue of Energy and Environment (2002) examining the barriers to nuclear phase-out. Major contributor to the SPRU study examining the economics of nuclear power plant decommissioning commissioned by the UK Radioactive Waste Management Advisory Committee (1993). Consultant to the International Atomic Energy Agency on nuclear power plant performance analysis.

Special interest in nuclear power technology, performance and policy in Eastern Europe and the former Soviet Union. Major contributions on Soviet nuclear technology to the study to determine the least cost method of replacing the output of the Chernobyl plants in the Ukraine.

Analysis of the market prospects of new reactor designs.

Analysis of the impact of electricity industry liberalisation on nuclear power. Research into structural change in the world electricity supply industries. Research on the impact of the privatisation of the British electricity supply industry and of the British gas industry. Major contributor to SPRU book on the British electricity supply industry reforms.

Analysis of corporate policies of internationally-based electric utilities. Detailed research in Brazil and Mexico comparing reforms to electricity industry there with reforms in Britain.

Member of European network of academics carrying out comparative research on reforms to European electricity supply industries.

Publications on nuclear power and electricity regulation

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