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The status of the Pebble Bed Modular reactor development programme

by

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1. Introduction

This report examines the position of the project by South Africa to develop the Pebble Bed Modular Reactor (PBMR) nuclear technology. It analyses the evidence that was publicly available up to the end of March 2007 (see Appendix 2 for main sources of information). It examines:

- The position of the proposal to build a Demonstration PBMR plant at the Koeberg site;
- The prospects for sales in South Africa and outside South Africa; and
- Commercial developments within the company developing the technology, PBMR Co, especially the prospects for bringing new, private-sector investors into the project.

1.1. Sources of information

The main publicly available sources of information on the PBMR programme are the Detailed Feasibility Report or DFR (PBMR, 2002a), the Final Environment Impact Report or FEIR (PBMR, 2002b) and the Revised Final Environmental Scoping Report (RFESR) published in January 2007 (Mawatsan, 2007). Also important is the Register of Comments and Responses on Draft EIRs (Register of Comments, 2002) published in June 2002, which contains responses to public comments on the draft Economic Impact Assessment. Note that the FEIR was substantially drafted before the withdrawal of Exelon. It contains a short section on the withdrawal of one of the partners in the project, the US utility, Exelon, but its sales projections are still based on Exelon buying the first 10 commercial units from 2006 onwards (PBMR, 2002b, p 194) even though it was by then clear that Exelon's commitment had lapsed with its withdrawal from the project.

The most comprehensive independent review of the economic prospects for the PBMR programme was published by Auf der Heyde & Thomas (Auf der Heyde & Thomas, 2002). An earlier response by the Legal Resources Centre drew partly on this paper and some, mostly inadequate answers were provided by in a Register of Comments (Register of Comments, 2002).

The main source for news items is the Platts trade journal, Nucleonics Week.

It is particularly regrettable that a report by an international Panel of Experts commissioned by the Department of Minerals & Energy (DME) to review the overall project has not been made public in any form. The report was expected to inform a Cabinet decision on the PBMR project. This Panel of fifteen international experts reviewed the overall case for the PBMR as presented in the Detailed Feasibility Study in 2001/02. They were given full access to all information they required and submitted a report to the DME in early 2002. The author of this paper was one of two experts assigned the task of reviewing the economic case.

However, the Panel members were required to promise not to disclose any information they learnt through their meetings and their report has not been made public. All the information presented here is available in publicly accessible sources. Panel members were assured by the DME that Eskom and PBMR (Pty) Ltd would not have access to their report, so it would appear that the only people that have seen the report are DME officials and Cabinet Members. PBMR (Pty) Ltd and Eskom cannot therefore claim that any of their evidence in the FEIR was endorsed by the DME review panel. Note that the DEAT also established a Review Panel to review the Draft Scoping Report for the EIR. The DEAT Panel was entirely separate from the DME's Panel, but like the DME's Panel, its report does not appear to have been made public.

It is difficult to know how the South African public can participate meaningfully in a decision on the PBMR if they do not have access to the most authoritative independent report on the project, that of the DME's International Panel. This need for information is strong because South African taxpayers and electricity consumers have funded most of the development work so far, and it seems likely they will bear an even higher proportion of the much greater costs and risks of building the Demonstration Plant. If the project proves a failure in the long-term, it will be the South African public that will end up bearing much of the cost.

There may, in some instances, be a case to withhold information contained in the Panel report or required to demonstrate the economic sustainability of the PBMR project from the public on grounds of commercial confidentiality. However, since the public is providing much of the funds the presumption should be that all information should be released and the onus should be on PBMR (Pty) Ltd to argue the case specifically where it does believe information should be withheld.

2. The PBMR project

The Pebble Bed Modular Reactor (PBMR) is a new design of nuclear power plant developed from two German designs, developed separately by Siemens and ABB. The nearest plant in design to the PBMR to be built was a demonstration plant in Germany, THTR 300, which was in service from 1983-89 (see Appendix 1 for a brief account of the technology).

2.1. Development in South Africa

The PBMR has been under development in South Africa since about 1993, although it was not until 1998 that these efforts were publicised. Eskom formally took a license with a German company, HTR, for pebble bed technology in 1999. The terms of this technology license have not been made public and the technology license is not discussed in the FEIR or the DFS. However, typically, a technology license would give the licensor a fee based on units sold, some rights over the new technology, and over the markets in which it could be sold.

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) 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 forecast by PBMR Co to be in service before 2012 at the earliest.

3. The feasibility phase

3.1. The partners in the feasibility phase

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 from reactor sales and servicing, fuel manufacture, to waste disposal became the first foreign investor in the project taking a 22.5 per cent stake in the venture. They were quickly 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. The South African government-owned Industrial Development Corporation (IDC) took 25 per cent of the venture leaving 40 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, 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 demonstration 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. It is not clear whether partners that did not take up their shareholding in the reconstituted company would be able to recover their share of the development costs, for example, by selling their rights to a third party.

David Nicholls, formerly PBMR project manger in Eskom, was the first Chief Executive Officer of PBMR (Pty) Ltd. He was succeeded in this post by Nic Terblanche, also previously with Eskom, when Nicholls moved back to Eskom in August 2003. In August 2004, Jaco Kriek from IDC replaced Terblanche and Alastair Ruiters of the South African Department of Trade & Industry became the Chairman.

Introducing partners to the venture had 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. The feasibility phase is now complete and the partners have no further legal commitment to fund the programme, leaving the project entirely in the hands of Eskom although the government appears now to be directing the programme. The partners however will be entitled to take shares in a newly constituted PBMR company if the demonstration phase is launched.

Since the completion of demonstration phase, further details have emerged as to what the partners actually contributed to the project and, in some cases, the contributions have been less than expected, leaving the South African government and/or Eskom to pick up the bill.

Nucleonics Week reported[1]:

> 'BNFL's contract [in 2000] gave it a right to a 20% stake to then, with an option for a further 15% over the following six months. At the time, it was reported that BNFL had "friends" that also wanted into the PBMR project, and quite soon Peco Energy, which later merged into Exelon, announced its interest in joining. Peco and BNFL, the source said, agreed that Peco would assume 12.5% of BNFL's 15% option, leaving BNFL with a total of 22.5%.'

Exelon's main 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

[1] Nucleonics Week, February 9, 2006, p 17

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 are 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.

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.[2] John Rowe, the new CEO of Exelon was quoted as saying: 'the project was three years behind schedule and was "too speculative,"'[3]. 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, by much more than a further three years. Despite claims by Eskom and PBMR (Pty) Ltd that a large number of interested replacement investors existed, no replacement for Exelon has been found. Ferreira, spokesman for PBMR (Pty) Ltd, stated in February 2006 that Exelon had fulfilled its obligation to meet 12.5 per cent of the development phase costs.[4]

BNFL's technical contribution appears to have been in fuel manufacture. At the time they joined the venture, BNFL's Westinghouse reactor vendor subsidiary does not appear to have been involved in the decision and it is not clear what input Westinghouse has had to reactor design. BNFL would have provided no significant advantages in terms of access to markets. However, BNFL and its Westinghouse subsidiary both supplied members to sit on the board of PBMR (Pty) Ltd.

BNFL had 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 company were abandoned and 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. In June 2005, the British government announced it was looking to sell the Westinghouse reactor vending, nuclear fuel manufacture and reactor servicing activities leaving BNFL as primarily a clean-up company. The Westinghouse division of BNFL was sold to the Japanese company, Toshiba, in January 2006. The stake in PBMR (Pty) Ltd passed to Toshiba and BNFL is no longer represented on the Board, although the decision to place the PBMR stake in the Westinghouse division placed no obligation on Toshiba to invest in the next phase.

When BNFL began to be broken up and sold off, it emerged that BNFL had not fulfilled its 22.5 per cent contribution and had only taken a 15 per cent stake.[5] A PBMR (Pty) Ltd spokesman, Tom Ferreira said BNFL "had a 22.5% stake until the end of 2003, after which they started diluting, with the South African government gradually taking up the rest of their stake."[6]

IDC's role in the project seems confused. IDC portrays itself as a skilled manager of technologically challenging projects. However, initially, it 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

[2] 'Corbin was the cheerleader for this technology, and without him, it can't go forward.' Electricity Daily, April 17, 2002.
[3] Energy daily, April 24, 2002.
[4] Nucleonics Week, February 9, 2006, p 17
[5] Nucleonics Week, February 2, 2006, p 11.
[6] Nucleonics Week, February 9, 2006, p 17

African public, it contributed nothing. Terblanche was quoted in August 2003 as saying the IDC would take no more than 12.5 per cent of the next phase.[7] 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.[8] However, since then, the role of IDC has been reduced again to that of no more than a passive partner. In August 2006, a spokeswoman for Minister of Public Enterprises Alec Erwin said that IDC would no longer act as the government's "nominee" or agent in the PBMR project.[9] It is not clear whether this means IDC would have no stake in the demonstration phase. It has also emerged that, unreported at the time, IDC had reduced its stake to 13 per cent in 2002.

These lower spends had left 60 per cent of the development cost in the hands of Eskom and the government. Eskom is reported to have spent about R1bn with the rest, especially costs since March 2004, when it appears the requirements under the development phase agreement were completed, being funded by government directly.

Nucleonics Week reported that[10]:

> '[A] source close to PBMR, who requested anonymity, said that investors in the project had for years been trying to keep developments commercially confidential, which made it difficult to grasp the evolution of the participation percentages over time.'

It seems regrettable that the impact of the decisions of private companies and, in the case of IDC, public agencies, to keep their contributions secret has meant that public money has been spent with no proper record or debate on how much has been spent and what it has been spent on.

3.2. The cost of development

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[11] 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 and IDC appear to have spent much less than they were 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.

It appears the feasibility phase formally ended in March 2004. Tom Ferreira, spokesman for PBMR (Pty) Ltd., said in February 2006 that historical costs of R1.4bn had been incurred up to March 2004, when it was decided that control of the project would be transferred from Eskom to the national government.[12]

Terblanche[13] indicated 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. In October 2004, the

[7] Nucleonics Week, August 28, 2003, p 1.
[8] Sunday Times, November 10, 2004.
[9] Nucleonics Week, August 31, 2006, p 3
[10] Nucleonics Week, February 9, 2006, p 17

[11] Nucleonics Week August 28, 2003, p 1.
[12] Nucleonics Week, February 2, 2006, p 11.
[13] Financial Mail, March 26, 2004, p 14.

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).[14] However, while this announcement was interpreted as government backing for the demonstration phase, it is not clear whether these costs should be categorised as demonstration or feasibility costs. In February 2005, when the government's budget was announced, the government support had increased from R500m to R600m. Even if spending since March 2004 had been no more than R50m per month, by the end of March 2007, a further R1.8bn of public money would have been spent since March 2004. This would have presumably been paid for, at least in part, by the R600m per year budgeted in February 2005, from central government sources.

Overall, substantial sums have been spent on developing the PBMR, probably in excess of R3bn. However, the next phase of demonstration will take the level of spending to a far higher level, requiring at least five times as much money as has been spent so far.

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

4. The demonstration phase

The main factors that must be considered in the economic analysis of the Demonstration Plant are:

- The partners, especially foreign companies;
- Safety licensing;
- Progress in identifying markets.

4.1. Potential partners in the demonstration phase

The demonstration phase was supposed to follow seamlessly on from the development phase, which appears to have ended in March 2004, but by April 2007, a commercial agreement to form the new company that would carry out the demonstration phase did not appear to be in sight.

In August 2006, a shareholders' agreement made a year previously between PBMR (Pty) Ltd, Eskom, the IDC and Westinghouse/British Nuclear Fuels plc (BNFL) lapsed. Under this agreement, government took 30 per cent, Westinghouse/BNFL 15 per cent, IDC 14 per cent, leaving the remainder (41 per cent) with Eskom). Ownership of PBMR (Pty) Ltd reverted to Eskom when this agreement expired although the government announced it would step in and direct the project through the Department of Public Enterprises (DPE).

In August 2006, a spokeswoman for Minister of Public Enterprises Alec Erwin said that IDC would no longer act as the government's "nominee" or agent in the PBMR project.[15] It is not clear whether this means IDC would have no stake in the demonstration phase.

At that time, it was reported there was still an outstanding the issue involving the technology license purchased from HTR. The owners of HTR are now Areva and Westinghouse (which inherited this through their merger/takeover of the previous owners, Siemens and ABB respectively). This was being negotiated between PBMR and Areva. A PBMR company spokesman called the issue "a formality" and said there was no reason the license could not be concluded[16]. It subsequently emerged that the issue was about the geographical scope of PBMR (Pty) Ltd's technology license, notably whether it can be deployed in the US. In September, confidence was expressed that the problem could be resolved soon allowing a new shareholder agreement to be reached. By April 2007, no shareholder agreement had been reached and no information was available as to whether the license problem had been solved.

The BNFL stake passed with Westinghouse to Toshiba, but, by April 2007, more than a year after it had taken on the PBMR stake, Toshiba had made no statement confirming that they expect to take any stake in the demonstration phase.

Eskom has said that it expects not to spend any more on the project and that would mean its stake would fall from the 41 per cent it took in the previous phase to about 5 per cent in the demonstration phase. So Eskom would remain a partner but would not provide any further funds for the demonstration phase.

It appears that by April 2007, the only confirmed funder for the demonstration phase was still the South African government through the DPE.

A number of other potential investors have been mooted and Eskom has had discussions with the French company, Areva, since February 2004. Areva is a publicly owned company with similar interests to BNFL. However, it has its own HTGR technology, which differs significantly from the PBMR (the fuel is prismatic rather than pebbles) and which Areva claims is superior to the PBMR.[17] It does not seem likely that the two technologies could be readily merged. Areva has shown no indication of being prepared to give its technology up in favour of the PBMR. It has also

[15] Nucleonics Week, August 31, 2006, p 3
[16] Nucleonics Week, August 31, 2006, p 3
[17] Nucleonics Week, March 25, 2004, p 6.

indicated that it is not prepared to fund the Demonstration Plant. Its interests and its potential contribution appear very similar to those of BNFL and it may not be possible to accommodate both in the next phase even if either company was interested and had the scope to participate.

Other potential investors, most recently Sasol, the South African synthetic fuels company, appear to be highly speculative.

4.2. Safety licensing efforts outside South Africa

It is acknowledged by all sides that for sales to most markets outside South Africa to be possible, certification by a highly experienced, high credibility nuclear safety regulatory agency is required. This is not to denigrate the competence of the South African regulatory authorities, but reflects the risk aversion of electric utilities and those that supply finance to power station construction particularly as electric utilities are exposed more to investment risk. One of Exelon's main contributions to the venture was their role in piloting the design through the US NRC procedures. The NRC had begun to review the design and had collaborated with the South African National Nuclear Regulator (NNR) on design issues but when Exelon withdrew, the NRC quickly wound down licensing activities.[18] It has been reported that PBMR (Pty) Ltd officials met with NRC officials in October 2004 to discuss design progress[19] and while further meetings have occurred since then it does not appear that NRC is carrying out any substantial design evaluation. In addition, there are now several other designs that are further advanced in the NRC's licensing queue ahead of it and it is not clear even if a design was submitted to NRC soon when NRC evaluation could be completed.

Without NRC approval for its design, it is not clear that the Demonstration Plant would have much value in promoting foreign sales. Until the design had been approved by the NRC and finalised, construction cost of the commercial export design cannot be estimated accurately. If the Demonstration Plant design differed significantly from what was required by the NRC (for example if the Demonstration Plant was built without a pressure containment and the NRC indicated it would require one for any plant built in the USA) potential buyers would see construction and operation of the Demonstration Plant as having only limited demonstration value

4.3. Safety licensing in South Africa

One of the major challenges of the PBMR programme has always been the burden it will place on the South African safety regulator, the National Nuclear Regulator (NNR), a body only established in 1999. Its predecessor body's only experience of licensing the construction of a nuclear power plant was the Koeberg PWR, ordered about 30 years ago. This was a well-proven design then and the common perception is that the South African regulatory body accepted the safety analysis from its home market, France. The situation today is very different. Even for a well proven design, a national regulator would have to complete a major evaluation of the design before approving it. Of course, if the design had already been approved by a high credibility regulatory body, the onus to repeat analyses would be reduced. However, the PBMR demonstration plant will be a First-Of-A-Kind (or FOAK in the jargon). NNR cannot rely on other agencies' analyses. If it makes a mistake or a misjudgment, it will be solely responsible and other agencies may rely on its analysis and judgments. This is a heavy responsibility especially for such an inexperienced regulatory body. The failure to progress licensing in the USA leaves NNR in a very exposed position.

Unfortunately, the NNR has been poor at communicating and repeatedly fails to respond to requests for information from the media. It has said it expects to take about two years to evaluate the demonstration plant design, when it is finally submitted to it[20]. However, it expects to issue partial licenses leading up to plant commissioning and start-up.

[18] Inside NRC, May 20, 2002, p 4.
[19] Nucleonics Week, November 4, 2004, p 1.
[20] Nucleonics Week, September 28, p 8.

This is troubling from two main angles. The US Nuclear Regulatory Commission (NRC), by far the most experienced regulatory body in the world is expecting to take up to four years to evaluate the FOAK designs it has in front of it now (it has taken longer in the past). These designs are FOAKs but are evolved from well-demonstrated designs, while the PBMR will be a much more radical departure from any reactor built and operated so far. How partial licenses would be used is unclear. If this means construction was to start before NNR had completed its evaluation, this would appear pre-emptive. Once construction has started, the NNR will be in a very difficult position if it then finds a need to require significant design changes. Some clarification from the NNR on what process it expects to follow and how the public would be informed and be able to participate in it would be welcome.

4.4. Possible time scales

In March 2007, a PBMR (Pty) Ltd spokesman admitted that construction on the demonstration plant could not start before late 2008 or early 2009[21]. However, this still seems a highly estimate. There has been no indication that the design of the demonstration plant is nearly complete. Given also that no commercial agreement to fund the demonstration phase has been concluded, it seems highly unlikely that a final design can be submitted to the NNR before the end of 2007. If we allow two years as the minimum time NNR could take before it allows construction to begin, this places start of construction at the start of 2010. A PBMR (Pty) Ltd spokesman has said that fuel load for the demonstration plant would take place 48 months after construction start. Allowing time for fuel load and other tests, first power might take place about 6 months later, at about mid-2014. This is now more than 10 years later than was forecast when the PBMR programme was announced in 1998. So despite nearly 10 years of work, completion of a demonstration plant is further away than it was when the programme was announced.

The original plan was that commercial orders would follow immediately on from the completion of the demonstration plant. This begs the question, what will have been demonstrated at that point? Clearly there will be some evidence on the design process, the constructability of the design, and the cost of construction. However, there will have been no demonstration of the operation of the plant. Given that the PBMR's nearest relative, the THTR-300 plant in Germany failed after the demonstration plant had started, this is an unjustifiable decision.

This issue was belatedly taken up in the Revised Final Environmental Scoping Report (RFESR) published in January 2007 (Mawatsan, 2007, p 55). It divides 'demonstration' into demonstration of functional integrity and demonstration of commercial performance. It lists 13 separate attributes that should be demonstrated. Three of these will take at least three years to be partially demonstrated (plant availability, plant efficiency and sustainability, operational and maintenance cost, and first outage). 11 of them will take at least 7 years to be fully demonstrated (e.g., main power system integrity and helium leakage verification). Even if operation goes entirely to plan and no problems emerge and we assume partial demonstration is a sufficient basis for commercial orders to be placed, this means commercial orders could not be placed before mid-2017, with first power from the first commercial plant in 2021.

Another major uncertainty is the Environmental Impact Assessment process. A positive Record of Decision (ROD) was given by the Department of Environmental Affairs and Tourism (DEAT) in June 2003. This was challenged in the courts by Earthlife Africa (ELA) and the Legal Resources Centre (LRC) and in January 2005, the ROD was overturned by the High Court[22]. It was not until two years later that a Revised Final Environmental Scoping Report was released. However, the consultants that wrote the RFESR withdrew from the project in March 2007. It is far from clear how long it will take for new consultants to be appointed and for them to produce a Final Environment Impact Report (FEIR), but given that it has taken two years to produce a Scoping Report, and new

[21] Nucleonics Week, March 22, 2007.
[22] Nucleonics Week, February 3, 2005, p 9.

consultants have yet to be appointed, it could still be at least a year before a new FEIR is produced. This must then be opened to public consultation, an evaluation of the consultation taken and the DEAT must then make a decision. Whether this process will take long enough to delay start of construction from the most likely earliest date of start-2010 is unclear, but the a positive ROD will not be obtainable much before then if a meaningful public consultation is to be carried out.

5. The commercial programme

Construction of the Demonstration Plant only makes sense if there is a high probability that it will lead to a profitable (to South African interests) 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.

5.1. 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 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.

Despite the fact that Exelon had already withdrawn from the project when it was published, the FEIR (PBMR, 2002b) still anticipated commercial sales beginning in 2006 with 15 units going to Exelon in the period 2006-8 and a total of 44 units by 2017. Eskom sales were expected to be at a much slower rate, starting in 2007, completing the 10-unit order by 2012 and ordering a total of 20 units by 2017. Other customers were expected to buy 76 units by 2017. So in the first 12 years of the commercial phase, the FEIR forecast sales of 140 units, a slightly faster rate of sales than the DFR.

Given that over the past decade, the volume of nuclear plant ordered has been only one or two 1000MW units a year, this seems far from conservative. In fact, it seems 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 significant 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.'[23]

[23] Nucleonics Week, September 2, 2004, p 5.

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 in the middle of a review of its nuclear power programme but its studies were based on using a large reactor design[24]. 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 seems 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 by ordering 10 units. It is clear this will not happen now and while some utilities offer supportive statements to the technology, as expressions of intent to buy plants, these are essentially worthless.

For example,[25] the CEO of Exelon (John W Rowe) was reported in May 2005 that:

> 'the high price of natural gas is an incentive to build new plants, but that an offsetting factor is the continuing low cost of coal. The lack of a solution for nuclear waste is also a deterrent.'

While the CEO of Dominion, another large US utility often mentioned when new nuclear orders are mooted said

> "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 competitor to the South African PBMR.[26] 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 seems 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 would compete with the South African design 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.[27] 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.

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[24] Department of Trade and Industry, 'The energy challenge', July 2006 http://www.dti.gov.uk/files/file31890.pdf
[25] M. Wald, 'Interest in Reactors Builds, But Industry Is Still Cautious' New York Times, May 2, 2005, p 19.
[26] Nucleonics Week, November 6, 2003, p 1.
[27] Nucleonics Week, June 23, 2005, p 8.

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, it seems a large proportion of the cost will therefore have to be borne by PBMR (Pty) Ltd.

5.2. The South African market for PBMRs

In the absence of foreign markets, this leaves Eskom as 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'.[28] Note that the DFR (PBMR (Pty) Ltd, 2002, p 50) misleadingly 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 2006, Alec Erwin, the Minister for Public Enterprises stated[29]: 'The current programme would be for Eskom and PBMR to negotiate an intention to purchase up to 24 reactors.'

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.

Given that commercial orders cannot be placed before about 2013 even on the most optimistic assumptions, such calculations are highly speculative. In that time frame, it cannot be assumed that Eskom will exist in anything like its present form and the attractiveness of alternative technologies, such as gas-fired plant and renewables could have changed dramatically.

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.'[30] 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 no more than the target cost of US$1000/kW, this would mean that Eskom was being asked to commit to making an investment of at least R25bn before the technology was economically or technologically proven. It seems highly unlikely that the units bought by Eskom could be sold at this price and the figure of R25bn is therefore at the bottom end of the likely costs.

However, the signs are that Eskom itself 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 stations only 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.[31] Clearly the PBMR, which cannot be in service as a commercial option before 2015[32] at the earliest, is of little relevance to this immediate need for new capacity.

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

[28] Nucleonics Week, August 28, 2003, p 1.
[29] Sunday Times (South Africa), June 11, p 1
[30] Nucleonics Week, October 7, 2004, p 3.
[31] Financial Mail, December 10, 2004, p 36.
[32] 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.

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.'[33]

This very much echoes the position taken by Exelon in 2002 when they withdrew from the project. These changes seem to be supported by the government. Nucleonics Week[34] 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. He said the IDC was to take over the leadership of the PBMR programme. 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".[35] He also seemed to suggest 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.'[36]

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[37], 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.

When the PBMR project was launched, it was expected to be primarily an export project producing about 30 units per year, with two thirds of the units for export. Thomas argued (Thomas, 1999) that the world market forecast was implausible and no more than one or two units per year would be sold. Eight years later, the overall world market for nuclear power plants looks no more promising and PBMR (Pty) Ltd has failed to identify any firm prospects export sales.

5.3. Benefits to the South African economy

The PBMR programme has always been sold to the South African public as a generator of jobs and wealth. Nicholls (Nicholls, 2000) suggested that the programme would generate 204,546 jobs and additional annual GDP of R18331m (the apparent precision of these inevitably highly speculative forecasts is grotesque). This was on the basis of a total market of 30 units per year, 20 of which were for export a local content of 50 per cent and 10 of which were for South Africa with local content of 81 per cent. The DFR (PBMR (Pty) Ltd, 2002a, p 55) projects annual sales of 10 units with local content for South African units of 69 per cent (48 per cent for the Demonstration Plant) and for export units, the South African content would be 43-65 per cent depending on the market (developed or developing country) and on how many units were sold. These are no more than

[33] Nucleonics Week, August 26, 2004, p 7.
[34] Nucleonics Week, September 2, 2004, p 5.
[35] Sunday Times, November 10, 2004.
[36] Sunday Times, November 10, 2004.
[37] Business Day, October 27, p 2.

targets and the actual percentage would be negotiated on an individual basis. If the market for PBMRs was disappointing or a large market was opening up, it may well be necessary to accept lower percentages rather than jeopardising sales. For example, China would be likely to require a very high local content.

Clearly the lower forecast sales volume and local content figures will dramatically reduce the jobs and economic effects forecast by Nicholls in 2000, perhaps by 75 per cent and the DFR showed figures of 63,719 jobs and GDP of R8522m (again grotesquely over-precise).

However, it is necessary to look at how these figures were generated. The DFR projects a unit cost for commercial units of about R180m. It forecasts that 40 permanent jobs will be created at the Demonstration Plant site plus about 1400 local construction jobs for about two years. The number of people working in manufacturing plants is forecast to be about 450 (PBMR (Pty) Ltd, 2002b, p 191). If we assume local content is on average about 60 per cent, this means the direct value to South Africa of 10 orders per year would be about R1000m. The number of direct jobs created would be of the order 1000.

It is therefore clear that projections of 60,000 jobs and GDP increase of R8.5bn must be based on 'second round' effects of jobs created in the companies servicing the PBMR programme, for example the steel industry might be able to sell some more steel and in jobs created servicing the needs of the workers employed. Complex computer models of the economy as a whole are used to model these effects but the results should be treated with care (see PBMR (Pty) Ltd, 2002a, p 55-62). Any large programme of spending, if fed into this type of computer model, would produce large numbers of extra jobs and a large amount of extra GDP. For example, if the South African government embarked on a large programme of construction of pyramids, this would generate new wealth and jobs perhaps in the cement and construction sector, but the money would be entirely wasted because the pyramids would be useless. The export orders for the PBMR would generate no permanent jobs in South Africa for operators, and few if any temporary jobs for construction workers, while the pressure from customers would be to maximise their local content, so factory jobs (and second round effects on supplying industries such as the steel industry) would be much less than forecast.

5.4. Risk analysis

The risk has always been that if international orders did not materialise, the South African public would be required to bail out the project by placing uneconomic orders. Thomas in 2000 wrote (Thomas, 2000):

> However, what will happen if Eskom does go ahead without major international collaborators and the stream of orders does not materialise? Will South African politicians have the nerve to write off the project or will plants be built ahead of need in South Africa just to keep the capability in existence? National flagship projects have a tendency to live long after they should have been killed off and South African consumers will end up paying for a series of expensive white elephants.

Even if the Demonstration Plant appears to be technologically successful (it will take several years of reliable operation before risk-averse foreign utilities will be convinced of this), that is no guarantee of international sales. PBMR (Pty) Ltd's cost projections for the commercial units are based on very large and still entirely speculative scale economies. If these are not realised, the commercial design would not be competitive.

The government appears to be acting to take control of the PBMR project away from Eskom, with IDC taking the lead role, while attempting to oblige Eskom to buy the plants. Eskom is being asked to invest more than R25bn in a technology for which the design is not even complete, let alone demonstrated and proven. To some extent, these changes will be of limited interest to the South African public. From a theoretical point of view, if the government is going to oblige Eskom to build more PBMRs than would be economically optimal, it should reimburse Eskom from taxes. However, the public may be largely indifferent whether they pay extra to subsidise PBMRs through their taxes or through their electricity bills. It will be much more concerned about the potential huge loss of public money.

6. The proposal for a 'conventional' nuclear plant

In April 2006, in the wake of severe power shortages in the Cape area following a serious error in the maintenance of the existing nuclear power plant at Koeberg, Alec Erwin, the DEAT Minister announced that he had asked Eskom to examine the possibility of building a 'conventional nuclear power station at Koeberg. By February 2007, these plans had been firmed up sufficiently that it was forecast that a large plant would be on line by 2014 with a total of 2000-3000MW to be completed in the 'near-term'[38] Are these plans any more realistic than those for the PBMR? A number of issues arise:

- What 'conventional' technologies are available and how proven are they/
- What regulatory burden would this impose?
- Is the timescale realistic? And
- How would such a unit fit into the South African system

6.1. What 'conventional' technologies are available?

The clear implication from the use by Erwin and Eskom of the word 'conventional' is that there are well-proven, off-the-peg nuclear designs that South Africa could order with confidence. This is far from the case. Of the reactor designs being developed and which are currently on offer, there are only two obvious candidates: the European Pressurised Water Reactor (EPR) offered by Areva; and the AP-1000 offered by Westinghouse.[39]

6.1.1. The EPR

The EPR (1700MW) has been under development by Areva since 1991, but only two orders had been placed by April 2007. One was placed in December 2003 for a plant to be built in Finland, while a second order for France is expected to be finalized in 2007. Experience with the Finnish reactor (Olkiluoto 3 has been appalling. After 18 months of construction, the plant was already 18 months late and the costs had escalated by about a third. While EPR has received safety approval from the French and Finnish authorities, it is not expected to complete its review by US authorities until about 2011. The EPR remains effectively unproven and experience to date is poor.

6.1.2. The AP-1000

The AP-1000 (1200MW) has been under development since 1999 and was given regulatory approval in 2006 by the US authorities (NRC). It was based on a design, the AP-600, which, after more than a decade of development, was given safety approval in 1999. However, by that time, it was clear the AP-600 was uneconomic and it was abandoned without ever having been built. In December 2006, China placed the first orders for an AP-1000 with four units. The AP-1000 is unproven and is based on a design that is also unproven. It has received regulatory approval in the USA, but nowhere else.

6.2. What regulatory burden would this impose?

The regulatory burden imposed on NNR by the PBMR will be a huge strain to its human resources. A 'conventional' nuclear plant cannot be 'nodded through' the safety regulatory process and a full evaluation needs to be undertaken, albeit that it can draw on existing work by the US, French or Finnish authorities. It seems improbable that NNR would have the resources to carry out a proper evaluation of the PBMR and a conventional nuclear plant to the required standard without serious delays to one or other of the programmes.

[38] Nucleonics Week, February 15, p 14.
[39] See S Thomas, P Bradford, A Froggatt, D Milborrow (2007) 'The economics of nuclear power' Greenpeace, London

6.3. Is the time-scale realistic?

If Eskom were to proceed with the conventional nuclear option, it would have to identify a site and open a call for tenders. Identifying a site would be hugely controversial and probably the least controversial site would Koeberg, where the existing nuclear plants are sited and where the demonstration PBMR is expected to be built. An EIA would have to be completed to get approval for a site and it is unlikely this could be completed and approval given in less than three years. A call for tenders could also take up to three years to be completed (China took longer before it ordered the AP-1000 units in 2006) once the call has gone out, vendors have developed and submitted their designs and costings, Eskom had evaluated the offers and awarded the contracts. So it would be a minimum of 3 years before work could start. Finland expected to build its EPR in 54 months but it is already 18 months late, France expects to take about 5 years to build its order and the UK projects a construction time of six years. All three countries have far more recent nuclear experience with construction than South Africa so a construction time of less than six years seems optimistic. So the prospect of having a plant on-line by 2014 seems improbable and even an accelerated process, where everything went without a hitch would be unlikely to see a plant on-line before 2017.

For comparison, Tony Blair was reported as saying that the latest UK plans meant that 'nnuclear power is back on the agenda with a vengeance'.[40] This was widely seen as foreshadowing a move that would see a rapid expansion of nuclear power in the UK. However, if we examine the plans in detail, in the central case, there would be a period of eight years in which safety approval was undertaken, a site identified and approved and contracts placed. This would be followed by a six-year construction programme with first power from a new plant in 2021, followed by 2-3 further units by 2026. Already, this timing has slipped when a High Court judgement ruled that the consultation process leading to Blair's statement was inadequate and would have to be restarted.

Nevertheless, the British timing of about 15 years from a firm decision to go forward with new nuclear programme to first power make Erwin's forecast of just 7 years seem highly optimistic

6.3.1. How would such a unit fit into the South African system?

The favoured site for both the demonstration plant and the first conventional nuclear plant is the Cape region, most likely the Koeberg site. This may well give some difficult logistical problems of trying to fit the construction of a PBMR, the construction of a conventional nuclear plant and the operation of a nuclear plant into one site. In addition, the power shortages of 2006 point to the problems of fitting large units into a region that has limited electricity demand and has limited connections to the rest of South Africa. The Cape region has a maximum demand of about 4000MW and two 900MW units, such as the existing plants, is difficult to fit in. If demand is about 3000MW at any one time, replacing the output of one unit, if it should break down is going to be very difficult. The EPR would be nearly double the output of each unit there now, while the AP-1000 would be about a third larger, so unless there was a huge strengthening of the transmission network to allow replacement power to be brought in when the plant breaks down (as it inevitably will on occasions), a large new nuclear plant would create almost as many problems as it solves. Of course, if the transmission network was strong enough to allow the siting of such a large unit in the Cape, then there would be no specific reason to site the plant there.

6.4. Summary

The proposal for a 'conventional nuclear' plant appears ill-thought out and unrealistic. Whether, as has been suggested by Erwin, it would be possible to proceed with both a conventional nuclear plant and the PBMR programme appears doubtful. Proceeding with both would risk scarce South African resources being spread too thinly with the result that, at best, neither project would be carried through efficiently.

[40] 'Blair to push for new wave of nuclear construction in UK' *Nucleonics Week*, 18 May 2006

7. Conclusions

The record of the PBMR venture in meeting time and cost deadlines is appalling. The estimated cost of the demonstration phase had escalated by a factor of more than seven by 2005. It seems unlikely that when an updated version of this cost is produced, the cost will not have risen again.

The estimated time when commercial orders could be placed has slipped from 2004 to probably no earlier than 2020.

There have been continual promises that new foreign partners would be brought in to the project to add expertise and share the risk but five years after Exelon withdrew, no new partners have been recruited. Indeed, all the original partners have either withdrawn or reduced their stake: Exelon withdrew in 2002; BNFL contributed only 15 per cent of the costs instead of the 22.5 per cent it was contracted to contribute; IDC reduced its stake from 25 per cent to 13 per cent. It has now emerged that even Eskom, usually seen as a committed supporter of the programme was, as early as 2002, concerned about the riskiness of the venture and was looking for politically viable ways to withdraw from the project.

The programme was launched on the basis of it being an export project that would bring a stream of income to South Africa **from export sales. This promise has also not been fulfilled and the any reasonably likely export orders disappeared when Exelon withdrew in 2002.**

The risk is that the longer the project continues, the more politically difficult it will be for the project to be abandoned and the pressure on Eskom to order plants will increase, regardless of how expensive these orders will be. As a fully state-owned company, it will be difficult for Eskom to resist this pressure.

The proposal from 2006 to proceed with a dual strategy of the PBMR and 'conventional nuclear' plants seems ill-conceived and it seems unlikely that South Africa could muster the resources to follow two different technological paths.

8. Appendix 1 The technology

The South African PBMR differs markedly from the designs of nuclear power plant that are dominant worldwide, the Pressurised Water Reactor (PWR, the type operating at the Koeberg site in the Western Cape, where Eskom expects to build the Demonstration Plant) and the Boiling Water Reactor (BWR) in five important respects:

- Coolant. The energy from a PWR or BWR is transferred from the nuclear core to the turbine (the equipment that transforms the heat energy into electricity) using water. The turbine, similar to that used in a conventional coal plant, is driven by steam. In a PBMR, the coolant is helium gas, which drives a gas turbine (similar to a jet aircraft engine);[41]
- Moderator. The moderator, the medium that ensures the energy of the nuclear reaction is efficiently exploited, is water in PWRs and BWRs, whereas it is solid graphite (a form of carbon) in a PBMR;
- Fuelling. In a PWR or BWR, the nuclear fuel is enriched (the proportion of the 'fissile' uranium isotope) from about 0.7 per cent in naturally occurring uranium to about 3.5 per cent. The fuel is in the form of uranium oxide fuel rods and the reactor must be shut down about once a year for about a third of the old fuel rods to be replaced with fresh fuel. In a PBMR, the fuel is expected to be enriched to about 8 per cent and is in the form of 'pebbles' the size of a snooker ball. These are continuously fed into the top of the reactor vessel and replace 'spent' pebbles, which are removed from the bottom of the reactor vessel;
- Size. A typical PWR or BWR produces an output of about 1000MW (1MW is equivalent to 1 million kilowatts), whereas an individual PBMR unit is expected to produce about 110-165MW;
- Modularity. The PBMR is conceived as modular and its economics are expected to be optimal if built in a group of 8-10 units, sharing some facilities such as the control room. PWRs and BWRs are generally built as individual self-sufficient units or in pairs.

All the major nuclear design countries have pursued high temperature gas-cooled reactor (HTGR) designs (those that use graphite as moderator and helium as coolant although not necessarily the other distinctive features of the PBMR) usually dating back to the 1950s, but none has resulted in a design that was built on a commercial basis. HTGR programmes existed in UK, France and Germany, but were abandoned, while research in Japan and USA continues only at a low level.

The PBMR is based on a German design of plant offered by a company called HTR. This company was based on an amalgamation of work carried out by two mainly German based companies, Siemens and ABB. ABB had built a demonstration plant, THTR 300, which achieved criticality (a sustained nuclear chain reaction) in 1983, but, after a very problematic history during which it operated for the equivalent of only about 30 full-power days, it was formally closed in 1989 because of a mixture of technical and economic issues. THTR 300 was somewhat larger than the PBMR (about 300MW) and also used a conventional steam turbine rather than a gas turbine (the coolant helium passed through a secondary circuit in which the energy was transferred to water) to generate the electricity. However, the 'pebble' fuel design was essentially the same as that expected to be used in the PBMR.

[41] Note that the Chinese version of the PBMR may use a steam cycle, at least for the initial units, in which the helium coolant passes through a heat exchanger in which steam is produced, which would drive a conventional steam turbine.

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