Nuclear energy rethink?

The rise and demise of South Africa's Pebble Bed Modular Reactor

INTRODUCTION

On 18 February 2010, public enterprises minister Barbara Hogan announced that, in line with the 2010 budget, the South African government had decided to cut its financial support to Pebble Bed Modular Reactor (Pty) Ltd (hereafter the PBMR company). This has probably put paid to the company's plans to build a demonstration model of a locally developed high temperature reactor, called the pebble bed modular reactor. Its name is such because it uses a technology involving pebble-shaped fuel elements and can be constructed in multiples called modules. As a result of the curtailing of state funding the company has had to restructure, with plans to dismiss over 75 per cent of its 800-strong workforce.[1] The PBMR company had absorbed R8,67 billion of taxpayers' money to date. It needed at least another R23 billion to set up the demonstration reactor and the fuel plant to make the pebbles. 'The problem with the project,' said Hogan, 'is that it has not been able to get a long-term investor and customer.'[2] The state was refusing to carry the bulk of the investment on behalf of taxpayers.

Although the PBMR company – first created in 1999 – is being left with a skeleton staff and a much smaller budget, it is not being closed completely. However, the retrenchments and the resignation of the company's CEO Jaco Kriek only days after Hogan's announcement have left the residue of employees deeply demoralised.[3] Kriek had earlier been given prominence in the South African news media in a vain attempt to curry Treasury and government support for prolonging the life of the project.[4]

Is the PBMR dead? Certainly it will not be able to rely on the level of state funding that it has received in the past. However, the company still operates and it is likely to engage in last-ditch attempts to find investors and customers. Westinghouse, which owns a small share in the PBMR company, has said it will make an additional investment to help the company survive for another 10–15 months.[5] Westinghouse, along with General Atomics, another US-based firm, wants to use PBMR technology to help the US Department of Energy to construct its own version of the high-temperature reactor in the USA.

Before leaving the PBMR company, Kriek claimed that government will make a decision about the future of the PBMR in August 2010.[6] This is likely to be part of a government pronouncement on nuclear policy in general. While the PBMR company has suffered a body blow in the removal of significant state finance, the spectre of its possible renaissance cannot entirely be ruled out for the moment. We therefore need to understand its history and prospects.

Originally the aim of the PBMR project was to deliver energy to industry and households, both locally and for export. It was foreseen that it would export 20 reactors a year and build about ten for domestic use. However, the technology has proven difficult for the South African team to master and the prospect of building a demonstration model has repeatedly been postponed. After initially setting the date for completion at 2003, the company continually deferred this and in 2009 announced it had rescheduled completion to 'round about 2020', a delay of at least 17 years (see Appendix I).

The design of the reactor itself has also been modified five times. At first the reactor was set to deliver 110 megawatts of electricity. Later, versions of 125 and 137 megawatts were claimed. In 2005 the design was further changed to allow for an output of 165 megawatts. This change was regarded as significant enough to have to reinitiate the environmental impact assessment (EIA) process to take the new design into account. However during the course of this EIA, a further significant modification to the design was announced. The PBMR company stated in February 2009 that the latest version would only generate 80 megawatts of electricity. It no longer claimed that the only rationale for the pebble bed reactor was the delivery of electricity. Instead, its purpose was said to have extended to the generation of heat for industry, the possible extraction of oil from tar sands, hydrogen production and the desalination of sea water.

South Africa was hard hit by an electricity crisis in January 2008. This was prefigured by a similar crisis in the Western Cape – home of South Africa's only nuclear power station – in the summer of 2005/2006. Although consumption had never exceeded the amount on paper that the electricity supply system could generate, for a number of reasons 25 per cent of the system was down at the time of the national crisis. Electricity consumers were subjected to random outages, with mining and smelting operations agreeing to a 10 per cent cut in their electricity use. It was clear that state-owned monopoly utility, Eskom, had mismanaged the situation, yet its earlier pleas to the state to support expansion of its generating capacity had been ignored. In attempting to rescue the situation, Eskom drew up plans for reopening formerly mothballed coal-fired power stations and building gigantic new ones to cover base load, supplemented by new diesel-fired and pump-storage stations to assist with peak load. Nuclear plans included the import of new-generation pressurised water reactors from either Areva or Westinghouse for location on the Agulhas peninsula and at Oyster Bay. Nowhere did the PBMR figure in Eskom's new plans for extending the country's capacity to generate electricity.

Cost and construction overruns have been a typical feature of the nuclear industry

In terms of costing the PBMR, Dave Nicholls, an early leader of the project, estimated in 1998 that the cost of getting the pilot reactor and fuel plant running would be R1,1 billion. In May 2005 this had escalated to R14,9 billion. Estimates doubled within four years, reaching R32 billion in August 2009. These estimates do not include operational costs, fuel costs, security provisions, ultimate waste disposal, decommissioning or insurance. Given that we can expect real costs to rise (for example, the cost of electricity is set to escalate significantly between 2010 and 2014), it is highly likely that the 2009 estimate will be greatly surpassed should the facilities ever materialise. Cost and construction time overruns have been a typical feature of the nuclear industry in general.

Given the immense cost, the minimal power dividend and the opportunity cost of foregoing smart development of clean energy resources, why did South Africa continue to sink huge resources into the PBMR project until recently?

To answer this, the following section reviews the origins and momentum of South Africa's nuclear industry. This is followed by a brief analysis of previous experiments with high temperature reactors in the United States and Germany and a glimpse at competition from China and elsewhere. A brief history of the PBMR project raises some governance issues with respect to regulation and environmental assessment procedures. The paper then returns to the current context in which the project's life has come under question and ends with some policy recommendations.

The course of the discussion raises broad questions about the relationship between mega-projects and development, about public policy making, about the special pleading of small lobby groups and about shaping democratic governance in a young democracy.

Why are there objections to nuclear power?

Nuclear power has long been questioned for reasons of health, environment, proliferation, expense, opportunity cost and governance. Radioactivity has affected the health of workers in the industry, as well as the general public, particularly when it spreads after an accident such as at Chernobyl in 1986. The most lethal radioactive waste needs to be insulated from the environment for a term of 244 000 years. The possibility of highly enriched uranium or plutonium forming the raw materials for nuclear weapons causes concern that if a country possesses the right links in the fuel chain, it will open up potential for the proliferation of such weapons. As nuclear materials may fall into the hands of traffickers or insurgents, the industry needs around it a vast security apparatus. As an expensive source of power, it crowds public investment out of less environmentally harmful options. As it is a centralised source, down time affects millions of people's access to energy. The nuclear power industry is often criticised for its dependence on subsidies, its exemption from insurance liabilities and for overruns in costs and construction time.

SOUTH AFRICA'S NUCLEAR PROGRAMME

Early integration into the global nuclear industry

The genesis of the South African nuclear programme took place in the second half of the 1940s. For the previous 50 years, uranium had been produced as a by-product of the rich goldfields of the Witwatersrand. However, for all that time no viable use was found for the mineral and it was dumped along with waste ore

in huge yellow mounds, which became a feature of the Johannesburg skyline.

During World War II, the influx of atomic scientists into the UK and USA from Europe alerted the Allied war effort to the possibility that there could be immense military potential in harnessing the power of the atom. Furthermore, it was likely that the Nazis had the same idea. The Allies were persuaded to construct nuclear weapons for deployment against Nazi Germany. Located at Los Alamos in the New Mexican desert, the weapons-development initiative was code-named the Manhattan Project. Two bombs were developed, but before testing was possible, Germany had surrendered. Instead the bombs were launched against Japan in August 1945.[7]

The race to drop the bombs was aimed at ending the war, but also at outflanking Stalin's offer to enter the war against Japan.[8] Suspicions grew as a new Cold War began and any plans to 'internationalise' control of the bomb through the fledgling UN were placed on hold. By 1949, the Soviet Union had developed its own nuclear weapons.

> Until the mid 1960s, the bulk of uranium destined for US and British nuclear weapons originated in South Africa

A global arms race unfolded, with each side stockpiling greater arsenals of increasingly lethal weapons. The efforts to manufacture these resulted in an enormous legacy of radioactivity in plants, cities and watercourses where proliferation occurred.

In building its weapons the Manhattan Project had relied on uranium sourced from the then Belgian Congo. Sources of the fissile material were rare at that time and, as the Cold War developed, the US and UK engaged in a global search to discover further supplies from friendly countries. In the course of this search, the South African prime minister Jan Smuts was approached. His officials recalled the publication of a scientific paper in the 1920s that had identified a significant presence of uranium in the Witwatersrand goldfields.[9] This unleashed a flurry of activity in which samples of South African ore were tested in laboratories of the MIT and the British Geological Survey, and found to be useful.[10] Subsequently, local gold-mining companies were approached to separate out the uranium from the gold-bearing ore at 17 sites, sealed by a secret agreement in which all the supplies would be purchased by the US and UK governments.[11] From the early 1950s to the mid 1960s, the bulk of the uranium destined for US and British nuclear weapons originated in South Africa. Thus, from the beginning of the Cold War, South Africa was integrated into the global nuclear arms race.

Development phase coincides with the onset of apartheid

Smuts used South Africa's role as a source of uranium to establish a Uranium Research Committee. However, it soon became clear that if the country was to develop its own research programme, it would require new institutions and legislation. The model used by Britain, the US and Canada was to establish a dedicated entity that had some autonomy from day-to-day government. Smuts decided that this model would also serve South Africa. Instead of entrusting the management to a department of government or an existing science council, such as the Council for Scientific and Industrial Research (CSIR), Smuts favoured the establishment of an Atomic Energy Board (AEB), which would combine the interests of government, researchers, mining and other industries. Legislation was passed and the date for the inauguration of the AEB was set for 1 January 1949.

What Smuts did not foresee was his loss of the (whites only) elections of May 1948. This saw the triumph of the Purified National Party, led by Dr D F Malan, who based his campaign on the policy of apartheid. This aimed at intensifying rather than ameliorating already existing racial segregation, further entrenching racial inequalities and smashing black opposition. Throughout the 1950s and 1960s, a spate of racial legislation increasingly diminished the rights of black South Africans, who were confined to bleak urban ghettos and rural dumping grounds, mostly without access to basic needs, including electricity. Most good jobs were reserved for whites and black labour remained menial and ill-rewarded. The country's economy boomed on the basis of racial exploitation. The presence of plentiful coal resources enabled the state's electricity utility, then called Escom, to provide white-owned industry and white households with electricity that was among the cheapest in the world.

The AEB was initially established to manage South Africa's uranium resources and to stimulate uranium-related research. Its offices were first in downtown Pretoria and its scientists became beneficiaries of Cold War era collaboration, being placed on secondment to the nuclear research laboratories in the US, UK and West Germany. Later this collaboration would extend to France and Israel.[12] Despite the growing daily injustices of apartheid, these links survived well into the 1980s.

As the AEB's research programme matured, it became clear that the cramped offices in the city were inadequate. In 1965 the headquarters moved to spacious farmland

located to the west of the city, on the banks of the Crocodile River. Named Pelindaba ('the talking is over'), the multi-building research complex was an architectural expression of late modernism, a signal that South Africa was at the global cutting edge of current technology. The AEB received direct support from the state and the prime minister at the time, Dr H F Verwoerd, known as the 'architect of apartheid', keenly backed an enhanced research programme.[13] This included plans to develop so-called peaceful nuclear explosives, aimed at assisting the mining and construction industries.

At the same time the AEB was taking advantage of the US's 'Atoms for Peace' programme. This was an attempt led by President Eisenhower to assist countries allied with the US in the Cold War to acquire nuclear technology for peaceful research purposes, in order to distract them from weapons proliferation.

Under this programme, the US delivered a small experimental reactor, which became known as SAFARI-1 and was installed at Pelindaba. This reactor was run on uranium enriched to the same grade (90 per cent) that was required for the manufacture of nuclear weapons. It still functions, being used for the production of medical isotopes and other technologies, although no longer requires to be run on weapons-grade uranium.

> The Pelindaba research complex was a signal that South Africa was at the global cutting-edge of technology

After Verwoerd's assassination, his former police and justice minister, B J Vorster, became prime minister. Vorster also took a strong interest in the potential of the nuclear industry and augmented the country's nuclear capacity. In 1970, he announced that the AEB would be reorganised into an Atomic Energy Corporation (AEC) and a separate Uranium Enrichment Corporation (UCOR). The country's first enrichment programme would be based at Valindaba, a farm adjacent to the Pelindaba complex. Vorster insisted in Parliament that all these activities would have strictly peaceful purposes.

However, although the nuclear programme provided the apartheid state with some leverage against full-scale isolation, geopolitical shifts were moving the country to a position in which Vorster could no longer uphold his pledge.

As a result of renewed war in the Middle East in October 1973, the petroleum exporting countries, organised as the Organization of the Petroleum Exporting Countries (OPEC), took a dim view of US and Western European support for the Israelis. In practice, OPEC decided on a fourfold hike in the price of oil, throwing world markets into disarray. Petro-dollars invested in western banks triggered off a combination of rampant inflation and industrial stagnation. Government finances were destabilised, causing an end to the post-war boom and the unravelling of the welfare state. The underlying energy crisis also contributed to shrinking of western economies.

The oil shock also affected South Africa, which due to its friendship with Israel, was subjected to an oil embargo. This led to strategic stockpiling of petroleum and extensive measures to save petrol, such as severe speed restrictions and bans on weekend sales. The crisis led to government doubling and later trebling the country's oil-from-coal production by the Suid-Afrikaanse Steenkool- en Oliemaatskappy (SASOL). Huge secrecy surrounded all the sanctions-busting measures that were undertaken.

A further bombshell impacted on South African security strategy. Following the Portuguese army coup against a longstanding repressive government in 1974, colonies such as Angola and Mozambique were rapidly granted independence under Marxist guerrilla leadership. In Zimbabwe, a full-scale liberation war was also under way. South Africa became enmeshed in a border war in the north of occupied Namibia against insurgent South West African People's Organisation (SWAPO) fighters, who were backed by the new Angolan government and increasingly by Cuban forces. South Africa intervened in the Angolan civil war on the side of the União Nacional pela Independência Total de Angola (UNITA) opposition, and became more embroiled in conflicts with the Cubans.

These changes posed a huge external threat to apartheid, as the frontline of its conflict with its neighbours now reached its own borders. No longer was there a ring of friendly regimes to act as a buffer. The prospects of an independent Zimbabwe and an independent Namibia would further intensify apartheid's isolation.

Apartheid looked in vain to the US for support, but superpower détente and post-Vietnam military exhaustion caused the US administration to resist further active entanglements abroad. Instead the South African government was left to its own devices in attempting to intervene in Angola.

Domestic resistance was also growing. Working class and black consciousness movements were drawing inspiration from the liberation struggles across the country's borders. The Durban strike movement of 1973

and the youth uprising that was initiated in Soweto in June 1976 sparked off waves of protest which challenged the apartheid regime.

These new features of the political landscape created a shift in nuclear policy. The energy crisis had led to a rethink about the need for diversifying dependence on oil imports, opening the way to new consideration of nuclear power stations. In turn, it was argued that such a programme would justify the domestic uranium enrichment facility. Once enrichment had been perfected, the spectre of weapons development could become a clear possibility. By the late 1970s, this option had begun to be realised.

South Africa and the bomb

The uranium enriched at Valindaba was ostensibly produced to build up sufficient fuel for Eskom's nuclear power station. However, in reality, the enrichment facility also served military needs. South Africa was therefore locked into the enriched uranium route to weapons production, rather than relying on plutonium like most other weapons nations. The enrichment process relied heavily on the work that South African nuclear scientists had done in West Germany, although they claimed that the process was a novel one. Protecting this intellectual property provided reason to keep the enrichment technique secret, and not to allow for inspection by the International Atomic Energy Agency (IAEA). The process was extremely costly and energy intensive.

> Atteridgeville's inhabitants weren't told that weapons of mass destruction were being assembled on their doorstep

By 1978, Vorster had given the go-ahead to the AEC to move from the development of peaceful explosives to the clandestine manufacture of nuclear weapons. His successor in office later that same year, P W Botha, continued to give strong endorsement to the programme.

The design of the weapons resembled the earliest gun-type device used on Hiroshima. The firing of one part of the device into another would detonate the nuclear reaction. Each of the bombs would utilise approximately 55 kg of uranium enriched to a level of 90 per cent. By 1989, six such weapons had been built and work was busy on a seventh.

The initial work took place in Building 500 at Pelindaba. However, as the programme developed, the AEC lost full control. Instead, the work fell to Armscor, the state's arms manufacturing and procurement agency, which used a number of key military personnel. The programme was moved to a dedicated building, the Circle factory (code-named 'Advena'), which was located closer to Pretoria in the Gerotek complex, most of which consisted of a vehicle-test track facility. The factory was set in the side of the Magaliesberg hills, only 4 km from the township of Atteridgeville, whose inhabitants were never informed that weapons of mass destruction were being assembled on their doorstep. Around a thousand people were said to have been involved in the bomb programme.

Was there any strategic value to the possession of these weapons? The South African Air Force never fully developed the capacity to deploy them, although attempts were made to acquire Israeli Jericho missile systems. The logic of targeting cities like Maputo, Harare, Lusaka or even Soweto would have attracted unwelcome accusations of racial genocide. Instead, the bomb makers later claimed that the devices were made to keep the world guessing about South Africa's nuclear weapons capability. Should there emerge the threat of a more overt attack, say by the Soviet Union, the existence of the weapons might then be revealed. The programme was thus seen as having purely deterrent value.

Nevertheless the programme developed a momentum of its own, with its manufacturers seeking to make progress away from the cruder gun-type devices. They began to explore the possibility of developing more sophisticated thermo-nuclear weapons. For this purpose, a new complex of buildings, code-named 'Ararat', was constructed in the vicinity of the Advena plant.

The Advena facility was built in such a way as to confound prying satellites. However a test range built at Vastrap in the Kalahari was not quite as invisible. It was first detected by Soviet satellites and Brezhnev communicated this to Carter, who put immense pressure on the South African government to close it down. A US Vela Hotel satellite also detected a 'double flash' in the far South Atlantic in September 1979, thought to have been a possible indicator of a nuclear test that South Africa may have facilitated for the Israeli military. Subsequently the US contested this version of events, but the matter remains inconclusive.

Nuclear power reactors

To justify the construction of a nuclear power station, the key question was the enhancing of energy security. Eskom also argued that it was extremely expensive and inconvenient to rail huge amounts of coal from distant fields to the Western Cape. Furthermore, as a uranium producer South Africa might as well use its resources for

local power production. Finally there was the prestige factor: South Africa would become the first African country to use nuclear power in its electricity grid and to take its place among the more technologically advanced nations.

However, the logic of placing the reactors in the Western Cape was flawed. Local electricity demand was not always sufficient to merit their full operation, leading to the reactors only being partly loaded for a considerable part of their early lives. This created technical and economic problems for Eskom. Electricity was generated well above the costs of coal-fired power.[14] Furthermore, the Western Cape was weakly connected to the national grid so that when the reactors were down, replacement electricity was difficult to source.

Plans unfolded concurrently with the weapons programme. In the mid 1970s Eskom purchased land at Duynefontein, a farming area on the Atlantic Ocean 28 km to the north of Cape Town. It invited tenders and had almost settled on a Dutch-led consortium when anti-apartheid forces persuaded the Dutch parliament to ask some awkward questions of the government. In the light of this, the tender was switched to a French-led consortium, which built two adjacent reactors on the site, now renamed Koeberg. Both were pressurised water reactors (PWRs), based on a Westinghouse design implemented by the French state-owned nuclear company, Framatome. They were able to generate a combined 1 842 megawatts of electricity at full output (compared with 80 MWe from a single pebble bed reactor).

Under the Key Points Act, government consultation with the Cape Town public was minimal

Delays in construction included a long period to refurbish damage from a bomb planted by an African National Congress operative in 1982. By late 1983 the first reactor went critical, to be followed by the second a year later.

Under the Key Points Act, government consultation with the Cape Town public was minimal and there was no impact assessment process in place. Opposition from the Cape Town City Council was ignored and its Medical Officer of Health decided to relocate away from any potential plume. Citizens were issued with iodine tablets but this was on a once-off basis. Eskom itself was placed in charge of evacuation and emergency planning. It should be noted that because the city is surrounded by mountain ranges, there are limited possibilities for evacuation to the interior. One of the main routes north passes the nuclear power station, so in the event of an emergency it would not be available.

Intermediate and low-level wastes are trucked over 400 km to a site in the Northern Cape called Vaalputs. Currently managed by the Nuclear Energy Corporation of South Africa (NECSA), the successor to the AEC, the site was originally identified without any public participation. In doing so, the AEC created 50 km no-go areas around what were then white-run municipalities, but Vaalputs turned out to be located within 24 km of indigenous Nama settlements in the Leliesfontein reserve. At times the regulator has had to close the site due to poor management of the radioactive wastes.

High-level wastes consist of the spent fuel. The used fuel rods are cooled off in ponds on the Koeberg site. After 10–15 years the rods are cool enough to be removed and stored elsewhere. However, no other site has ever been prepared for the accommodation of these high-level wastes. Instead, the ponds at Koeberg are periodically re-racked in order to accept more and more of the spent fuel. This points to the fact that until 2005, there was no formal policy on the storage of nuclear waste. Even when the Cabinet eventually approved a policy document, this did not really relieve the problem of high-level waste storage. The policy merely offers future options – either deep-level geological disposal, or reprocessing, neither of which are close to being chosen. Reprocessing entails the removal of some of the radioactive materials like plutonium for further use, but cannot treat all the high level waste and generates further low- and intermediate-level wastes. Reprocessing is therefore a highly inadequate solution to the management of radioactive waste.

Closing down the weapons programme

P W Botha's rule was characterised by increasing militarisation of the state, strong repression (including two states of emergency), regional aggression, and intransigence towards social and political change. Instead of granting more rights to black people, he introduced a convoluted system of three ethnic parliamentary chambers (white, 'coloured', and 'Indian'), excluding the black majority from any elected central representation. The economy began to feel the pinch of sanctions, an investment drought and extensive corruption. Resistance to apartheid took heart from international solidarity and mass organisation grew throughout the 1980s. Botha was unable to respond creatively to the demand to release Nelson Mandela. In 1989, he was smitten by a stroke and left politics, a bitter and isolated figure.

White politics had begun to change. Botha was succeeded in office by F W de Klerk. Although extremely conservative, de Klerk had come to the realisation that

power had to be shared. He soon released political prisoners, including Mandela, unbanned illegal parties, canvassed support for change from white voters in a referendum and began negotiations over a democratic transition. While a new democratic dispensation was being crafted, the nation experienced a new phase of violence, some of which was provoked by the acts of sectarian ethnic nationalists, death squads and rogue 'third force' members threatened by the prospect of a non-racial future.

In the context of political change, one of de Klerk's earliest presidential decisions was to dismantle nuclear weapons. Armscor and the AEC carried out the work in 1990 so that, by the following year, inspectors from the IAEA were able to visit the decommissioned Advena plant and Pelindaba's Building 500 and satisfy themselves that the programme had ended. After years of expulsion, South Africa was readmitted to the Treaty on Non-Proliferation of Nuclear Weapons (NPT) and resumed its seat at the IAEA in Vienna. For some years South Africa was celebrated as being the first country in the world to dismantle its nuclear weapons voluntarily.

South Africa was celebrated as the first country to dismantle its nuclear weapons voluntarily

Why had de Klerk made such a move? By 1990 it had become clear that the Cold War was at an end. The Berlin Wall had fallen and there was a serial collapse of former socialist governments in Eastern Europe. The Soviet Union was deconstructed into its constituent parts, each achieving its own sovereignty. No longer could South Africa use the logic of needing weapons to curb the spread of global communism. Secondly, de Klerk was mindful of the extremely high cost of keeping the weapons programme going in the context of the economic difficulties of the last years of apartheid, and knowing that they would never be used. Thirdly, de Klerk deemed that, with an imminent regime change in which the African National Congress was likely to take power, it would be too risky to allow the new government to inherit weapons of mass destruction. To guarantee that there would be no retribution against those involved in the programme, de Klerk ordered that all its records be destroyed.

In subsequent years, no accountability for the manufacture of these weapons was assigned. For example, the matter never came up in the course of the Truth and Reconciliation Commission (TRC), whose brief was limited to violations of individuals' human rights. Instead, the bomb manufacturers are still with us and we know little of who they are. Some have joined academia, some emigrated to run an explosives factory in Namibia, some returned to Armscor (now Denel) and the AEC (now NECSA). Others set up their own manufacturing companies, later being arrested for trafficking in parts for the manufacture of nuclear weapons elsewhere. And some ended up maintaining their connection with the industry by proposing that a new high-temperature reactor based on pebble bed technology be adopted in South Africa.

Nuclear policy under democracy

With the imminent democratisation of South Africa, critics of the apartheid nuclear programme saw an opportunity for a new beginning. The danger of proliferation was no longer an issue. The costs of running expensive enrichment plants and fuel fabrication facilities seemed luxurious in the face of the country's serious development needs.

One way of proceeding was to rethink the way in which the assets of the nuclear industry could be redeployed. The human capital was highly skilled, but could be used for more socially useful purposes. The physical assets of the Pelindaba complex could be transformed into a campus that could house a technological university, a series of laboratories to develop renewable energy or even an environmental protection agency.

On the eve of political change the ANC's Science and Technology desk in the Western Cape and the Environmental Monitoring Group (EMG), an NGO, joined to organise a conference on the future of the nuclear industry. While the meeting challenged the nuclear industry to convert to more socially useful science, there was no indication from the ANC that this would be considered. The only change in attitude seemed to be an assurance from Trevor Manuel, then heading the ANC's economic desk, that future decisions on the industry would be made more transparently. Said Manuel:

> We shall not tolerate circumstances in which policy on issues as critical as a nuclear programme be confined to experts in dark, smoke-filled rooms. The debate must be public and the actions transparent.[15]

On 24 March 1993, President de Klerk made public the information that South Africa's nuclear weapons programme had been terminated. ANC representatives were invited to visit Pelindaba and Advena so that this could be confirmed. The weapons-grade uranium had by

this time been removed from the weapons and was stored under IAEA-approved safeguards at Pelindaba.

With the change in administration just over a year later, the AEC continued to engage in nuclear research. Its commercial arm carried on with production of medical isotopes and solutions to dust filtration problems in the country's mines. It embarked on the development of a laser-based enrichment technology (molecular laser isotope separation, MLIS), hoping to commercialise this. It started to decommission its existing enrichment plants and sold off the fuel fabrication equipment to China. Neither of these had been commercially successful. Nor could the AEC find an investment partner for the MLIS project so it was dropped. And to demonstrate its new adherence to fiscal propriety, it dismissed a few thousand workers. All these initiatives were designed to demonstrate to the incoming democratic government that the AEC was not a financial drain and could be useful to the new government.

Capitalising on the kudos derived internationally from the voluntary end to its weapons programme, the new government strongly promoted the idea of Africa becoming a nuclear weapons-free zone, along the lines of those established for regions like Antarctica, the Pacific, Latin America, south-east Asia, central Asia and outer space. Tough negotiations ensued, especially because it was important to include in the treaty those weapons states which had strong connections with Africa. One sticking point was the US nuclear weapons base on Diego Garcia, an atoll in the Chagos Islands of the Indian Ocean.[16]

The new government strongly promoted the idea of Africa becoming a nuclear weapons-free zone

In 1996, the wording of the new instrument was finalised in Cairo, but named the Treaty of Pelindaba. It took until 2009 before a sufficient number of signatory nations had ratified it to allow it to come into operation.

A further innovation was the creation of a Council for the Non-Proliferation of Weapons of Mass Destruction, aimed at preventing the development of nuclear, chemical and biological weapons. Initiated as a result of a law promulgated in 1993, the Council is accountable to the Department of Trade and Industry.

When a series of individuals linked to the former bomb programme were arrested in September 2004, it became clear that they were implicated in trafficking of dual-use equipment for enrichment technology as part of the ring of suppliers organised by Dr A Q Khan, the 'father' of the Pakistani bomb. Mr Johan Meyer was accused under the Non-proliferation of Weapons of Mass Destruction Act (No. 87 of 1993) of trafficking but turned state witness against two of the other accused in a trial which the government tried but failed to hold in camera after being challenged by the Freedom of Expression Institute. Further members of the South African section of the ring were arrested in Germany and the US.

Given the clear stance on proliferation, the real test of nuclear policy was the extent to which nuclear would be a component of South Africa's future energy mix. Under the Mandela presidency there was extensive public consultation on different policy issues, including energy. Government hosted an energy summit process in which popular participation was welcomed. At the main national event, stakeholders from civil society in all provinces were included and given support in making an effective contribution. The Energy Summit took place in 1995, and was one of the steps taken towards the emergence of the White Paper on Energy Policy (the White Paper), which outlined policy and legislative intent. By the time of the Summit the AEC had significantly scaled down its operations and staffing. The future of the Koeberg nuclear power station was also under question at the time. However, in the final White Paper, published in July 1998, specific reference was made to the expansion of the nuclear industry, which, it stated, would only occur in the context of:

> an integrated energy policy planning process with due consideration given to all relevant legislation, and … subject to structured participation and consultation with all stakeholders.[17]

The White Paper also signalled that there would be some restructuring of the nuclear industry 'necessary to ensure the environmental sustainability and cost-efficiency of South Africa's energy economy, while seeking maximum benefit from historical investment.' This restructuring would be undertaken in 'a participatory fashion', and, before any final decision was made on the future of Koeberg, there would be a full-scale investigation into its financial and technical performance 'made available for public scrutiny and comment'.[18]

However, taken together with Trevor Manuel's earlier pronouncements guaranteeing transparency, these promises in the White Paper have not materialised. This could partly be attributed to the less open politics of the incoming Mbeki presidency in May 1999. The subsequent drafting of the Nuclear Energy Act No 46 of 1999 and the National Nuclear Regulator Act No 47 of 1999 took

place within the Department of Minerals and Energy (DME), the only consultation being with the Chamber of Mines, representing the larger mine owners. This was in sharp contrast to the more participatory style of policy formulation during the previous Mandela presidency. In addition, the period allotted for comment on the National Radioactive Waste Management Policy and Strategy was so inadequate that the minister was forced to extend it for an extra 90 days to accommodate public comment. Very few of the public concerns were reflected in the final policy document.

The question of adequate public consultation also dogged the process of formulating the Nuclear Energy Policy document. This was placed in the public domain for a limited period (coinciding with the height of the summer holiday season) and government announced that only 26 comments had been received, mostly from within the nuclear industry itself. As a result officials felt it was able to proceed to Cabinet for approval, which occurred in 2008.

There has thus been no broad stakeholder consultation on the future of the nuclear industry; nor has this applied specifically to the future of Koeberg, as promised in the 1998 White Paper. Most of the decision making on the industry has been centred on the DME (Department of Energy since May 2009), and the Department of Public Enterprises, which oversees Eskom. The decision making has been from the top down, without any significant stakeholder participation. What appears to be government policy has been formulated without any policy debate on these matters having taken place within the policy arenas or local structures of the ruling ANC party.

There has been no broad stakeholder consultation on the future of the nuclear industry

This lack of transparency is symptomatic of how the executive branch of government has come to dominate national policy making. Cabinet has become susceptible to the special pleading and some of the false claims of the industry.[19] As a result, the nuclear lobby has retained its highly subsidised place in the sun at the expense of cleaner technologies, human health and the environment.[20]

The nuclear lobby

Formerly dispersed across a number of institutions, the nuclear lobby has become more sophisticated. It recently took the form of a body called the Nuclear Industry Association of South Africa (NIASA). Not only was the PBMR company a founder member of NIASA, but it originally hosted the NIASA secretariat.

The contours of the lobby are revealed when we examine the membership of its current board:

- Sponsor members include NECSA (in the person of CEO Rob Adam, who is NIASA president), Aveng (a private construction company whose CEO Roger Jardine formerly chaired the NECSA board), Westinghouse (an investor in the PBMR), Mitsubishi Heavy Industries, Areva and Eskom
- Elected members hail from a mix of the private sector (Steinmuller, M-Tech Industrial, Aberdare Cables, KOG Piping), parastatal research entity (iThemba LABS) and academia (Universities of the Witwatersrand and Pretoria)
- Ex-officio members include the NIASA CEO Ayanda Myoli (seconded from NECSA), Prof Krish Bharuth-Ram (former chair of the board of the National Nuclear Regulator –NNR), Tony Stott (Eskom) and Jean Venter (Van der Walt and Associates).

Jaco Kriek, the outgoing CEO of the PBMR company, is said to have been 'one of the driving forces behind the creation of NIASA'.[21]

In addition the industry has begun to play the gender card in organising an entity called Women in Nuclear. This relies on a membership of professional women in the industry. It has been supported by a series of female ministers and deputy ministers and seeks to increase the representation of women inside the nuclear establishment. Women have been ministers in the departments of minerals and energy (now divided and each led by a woman), water, environment and public enterprises. None have stood up to the nuclear lobby.

The lobby is interested in the PBMR company repositioning itself as an engineering design firm and sees it as playing a role in helping to drive a localisation initiative that will assist the industry's future expansion.

THE INTERNATIONAL EMERGENCE OF HIGH-TEMPERATURE REACTORS

High-temperature reactors have been the focus of research since the 1950s. Experimental reactors were built and operated in the 1960s and 1970s, particularly in Germany and the US. In more recent years, interest in these reactors has spread. How are they different to the conventional reactors and why have they found favour among certain developers?

What we call 'conventional reactors' were developed from the 1950s to the 1980s, and use a variety of technologies. Some early reactors,[22] including the first reactors

in France and Britain and those produced in Canada and sold to India,[23] are able to use raw, un-enriched uranium to develop nuclear fission. The rest require the use of enriched uranium. Most of the over 430 reactors in the world conform to either of two basic designs: PWRs, as at Koeberg, and boiling water reactors (BWRs). In the PWR, the coolant water is pressurised to remain a liquid and passes through a heat exchanger in which water boils and the steam drives the turbine generator that produces the electricity. In the BWR, the reactor coolant is allowed to boil and drives the steam turbine directly.

PWRs need to be built by the sea or adjacent to a large inland body of water, which is used to condense the steam in the power generation circuits. The nuclear fuel is supplied in pellets that go into cylindrical metre-long steel rods in a cladding made of zirconium and hafnium. To obtain a nuclear reaction, an assembly of rods has to be inserted into the reactor core and bombarded with neutrons emitted naturally by the uranium fuel, causing fission. The heat produced by the reaction is passed on to the coolant, which absorbs it in a separate loop and passes it on to a boiler, whose steam drives a turbine, thus generating electricity. Usually the reaction is isolated from the environment by means of a containment building. However, in the case of the Chernobyl reactors,[24] no containment building existed and when the accident occurred in April 1986, radioactive contamination passed throughout Europe.

> By the mid 1990s the nuclear industry began to regroup

The accidents at Three Mile Island in the US, and Chernobyl in Ukraine (then part of the USSR) set the nuclear industry back significantly. As a result, orders for nuclear reactors dried up and the industry lost support and investment. In Europe and East Asia, active anti-nuclear movements played a part in lobbying governments to end their nuclear programmes. In countries like Austria, Italy and Sweden, referenda pronounced against further expansion and in favour of closure of the industry. Germany, during a coalition government between Social Democrats and Greens, declared a phasing out of its nuclear programme.

There were also economic considerations. Without strong financial support from governments, including insurance waivers in case of accident, reactors were seldom viable or took many years to pay off their debts. The World Bank would not fund the industry.[25] The Kyoto Protocol did not regard nuclear as a technology beneficial to climate change, excluding it from consideration in crafting a Clean Development Mechanism.[26]

By the mid 1990s, the industry began to regroup. In order to interest politicians in helping to salvage its future, something new had to be offered. The major vendors developed redesigned and updated (Generation III+) PWRs and BWRs. Renewed interest in high-temperature reactors by some governments and companies began to be manifest in various countries around the world (see Table 1).

High-temperature reactors differ from their PWR predecessors in a number of ways. They are generally much smaller and produce a smaller amount of power. They are mostly designed to use inert helium gas as a coolant rather than water. Although they run at high temperatures, they are designed to close down automatically if they exceed the normal range. South African nuclear engineers working on the PBMR have termed the reactor 'inherently safe', because they are said not to need human intervention in these situations. However, this is misleading as it is impossible for a large volume of radioactive material to be 'inherently safe'. The reactor may not run a high risk of melt-down, but many other things can go wrong, including a hydrogen explosion.

In high-temperature reactors like those that were designed in Germany (such as the South African PBMR), the fuel that is used is contained in billiard-ball sized spheres called pebbles. At the core of the pebbles are tens of thousands of tiny radioactive particles embedded in a graphite matrix, surrounded by a series of barriers including a layer of silicon carbide, which is too dense to allow the radioactivity to escape. Between 360 000 and 440 000 pebbles will enter the reactor; of these about seventy-five per cent will contain radioactivity. The rest will consist of pebbles containing graphite alone, used as a moderator in the reaction. The active pebbles circulate through the reactor about six to ten times during the course of their lives. The pebbles use the energy produced in the chain reaction much more efficiently (~45 per cent) than does the fuel inside a PWR (~33 per cent).

Promoters of the technology have been able to claim that it is a theoretical advance on the PWR generation of reactors. They argue that the new generation reactors are safer, are smaller and thus less costly, are modular[27] and hence versatile and can be built close to specific industries or adjacent to residential areas. They are subject to less routine maintenance and there is less down time than with PWRs. The waste can be stored on site and therefore only needs to be transported at the end of the life of the reactor. Reprocessing of the spent fuel would be too complex and expensive to undertake and the integrity of the pebbles means that they cannot be used in weapons manufacture. Finally, unlike the PWRs, they can be designed to produce not only electricity but also

heat for industrial processes, as well as being used for hydrogen production and in desalination processes.

Sceptics challenge some of these claims. The argument that they are smaller and therefore less costly is misleading since smaller reactors are likely to cost more per unit of output. Until a demonstration model has run for a considerable time, it would be hard to justify claims about less maintenance and down time. The proliferation argument cannot absolutely be guaranteed. And on the question of safety, some nuclear experts are concerned about the possibility that graphite could catch fire under certain circumstances. Other concerns include the problem that some designs, including the first version of the South African PBMR, made no provision for a containment building. This concern was raised in the EIA process and the PBMR company engineered a subsequent version to include a containment building. This concern arose through the experience of the Chernobyl accident. Critics also point to the German experience. In particular, the case of the thorium high-temperature reactor, THTR-300, was not an entirely successful one.

Graphite could catch fire under certain circumstances

The German experience

Much of the technology for the high-temperature reactor was developed in West Germany between the 1950s and the 1980s. The design was originated by Professor Rudolf Schulten of Aachen University in Germany in the 1950s. Schulten pioneered the notion of nuclear fuel in the form of a pebble. New understanding of the containment properties of silicon carbide and pyrolytic carbon, being extremely strong at high temperatures, led to their use in the outer shell of the pebble. The design was simpler than previous types of reactors, with greater safety features.

Fifteen German municipalities organised a Joint Working Group in the 1950s to explore the construction of a high-temperature gas-cooled reactor (HTGR). By 1959 they had ordered the Joint Working Group to produce an experimental reactor (the *Arbeitsgemeinschaft Versuchsreaktor*, or AVR) at Juelich. The idea was to build a small reactor based on pebble bed technology that would generate 15MW of electricity. It took until 1966 for the AVR to be built and it generated power from 1967 to 1988. During its lifetime it acted as a kind of prototype and research model for the development of pebble fuel elements. Much of the experimentation was conducted by the Nuclear Research Facility (KFA) in Juelich (later renamed the Juelich Research Centre, FZJ). Because the temperatures in the reactor were extremely high (unintentionally going beyond the stipulated ceiling of 900 °C), some fuel types failed during experimentation.

The closest precursor of the PBMR, which used similar fuel pebbles, was the THTR-300, built at Hamm-Uentrop in Germany from 1971. The plant, which was aimed at providing electricity to the grid, went critical in September 1983, but only began delivering commercial power in June 1987 due to extensive teething troubles. Normally it should take a maximum of six months before full power is delivered. One of the problems was the 'fuel pellet incident' of 4 May 1985, when a pebble became stuck in a fuel feed-pipe leading to the core. After further problems were experienced, mainly with fuel circulation, the reactor was shut down due to damage to the gas ducts in April 1988. It never re-opened because the owners, HKG GmbH, and the federal German government were unwilling to subsidise further development.

Studies recently published by the Juelich Research Centre show that lessons from the German experience with regard to the safety of pebble bed reactors have not yet been fully learned. Rainer Moormann, a Juelich scientist, points to the 'over-optimism' of the proponents of pebble beds, challenging their claim that the reactors are 'inherently safe', by listing a number of serious problems and omissions in research and development. Correcting these will be costly and will further damage the suppliers' claims that the technology can be economically viable. Moorman concludes that while

> pebble bed reactors contain certain inherent safety features compared to conventional reactors, they are however to some extent compensated by inherent safety problems. Some of these inherent safety problems can be solved by adequate safety measures or by R&D, but it remains uncertain whether this is possible in an economic manner. With pebble bed reactors, there is a trade-off between economy and safety.[28]

US forebears – experience of Fort St Vrain

In 1965, the US Atomic Energy Commission announced plans to build a 330 MWe high-temperature gas-cooled reactor at Fort St Vrain, close to the Rocky Mountains. Work was initiated on the site in 1968, the reactor opened in 1972, and, after a test period, commercial electricity was generated for the first time in 1976. In 1979 the operation was handed over to the Public Service Company of Colorado, the state electricity utility. The reactor operated for 13 years but was plagued with enormous operational problems, which eventually overwhelmed the company. These included a series of power fluctua-

tions that required extensive shut-downs, the jamming of control rods and the leakage of water into the reactor core. The regulator fined the company for down time and made it pay compensation to consumers. Costs escalated alarmingly and by August 1989 the utility took the decision to close the reactor. It took until 1992 for the fuel to be removed and the whole plant was decommissioned by 1995. Over the last ten years of its life, the reactor had only operated 15 per cent of the time. The site was later converted to a natural gas power station. Although Fort St Vrain did not use a pebble bed technology, it was the US's earliest high-temperature helium-cooled reactor and the first US reactor to be decommissioned.[29]

Significance

What is significant about the pre-1990 history of the high-temperature reactors in Germany and the US is that they provided practical operational experience rather than theoretical consideration of how the reactors would function. In two of the three cases (Hamm-Uentrop and Fort St Vrain) there were serious operational and financial problems. In all three cases the reactors were closed down and decommissioned, perhaps before all the operational lessons could be learnt.

If the new generation of reactors is to benefit from such lessons, perhaps there needs to be less complacency about claims of inherent safety and more attention to the checklist produced by Moormann in his evaluation of the AVR and HTR-300 experiences in Germany (see Box 1).

A further link with the previous generation's efforts on the pebble bed design exists in the form of proprietary rights to the design. Both the South African and Chinese pebble bed reactors are being built on licence to the German company Gesellschaft fuer Hochtemperaturreaktoren (HTR GmbH), owned jointly by ABB and Siemens.[30] For each PBMR built locally or exported from South Africa, HTR GmbH will have to be paid a royalty.

Current producers

The most significant high-temperature reactor projects are listed in Table 1. Most of the US efforts are still on the drawing board, whereas China and Japan have already moved to pilot projects. The South African PBMR also remains on the drawing board, but some of its design components have been pre-tested at the University of the North-West's Potchefstroom campus, others at Pelindaba and in Russia. Agreements have been reached on some co-operation between the Chinese and South African companies. While there are some similarities in design between companies, there are also some important variations.

China is the closest to the commercialisation of the pebble bed reactor and hopes optimistically to roll out 30 of them in the next ten years. There has been some collaboration between the Chinese manufacturers and the PBMR Company to date, formalised in a Memorandum of Understanding.[40] Whereas the earlier designs of the South African PBMR were developing a direct-cycle gas turbine system, the Chinese model has an indirect-cycle steam turbine system.

With the third redesign of the South African PBMR (see the next section), the emphasis is somewhat less on energy production and so it may switch to an indirect cycle. This implies more convergence between the designs proposed for the South African and Chinese reactors. This may increase the levels of collaboration between the two projects.

Box 1: Suggestions for addressing the safety concerns about current pebble bed reactor designs[31]

- The design of a gastight containment
- Full evaluation of the operational experience and problems of AVR and THTR300*
- Development of a new fuel element that sufficiently retains metallic fission products over long-term operation
- Development of reliable quality control for fuel elements
- Experiments on iodine release from fuel elements in core heat-up accidents*
- Examinations of unexpected particle failures as observed in experiments with realistic core heat-up transients
- Full understanding and reliable modelling of core temperature behaviour, and of pebble bed mechanics, including pebble rupture*
- Experimental and theoretical examinations of dust formation under real PBR conditions
- Development of a fast and reliable local measurement method (whether direct or indirect) of safety parameters in the pebble bed core, such as temperature
- Full understanding of fission product transport in the coolant circuit, including dust influence
- Development of measures to avoid activity accumulation in the circuit
- Full understanding of the cobalt-60 contamination of the primary circuits of AVR and THTR300
- Development of a fast detection system for metallic fission product release from core
- Material development for nuclear process heat components
- Development of high-temperature reactor- (HTR)-specific dismantling and disposal items

Meanwhile, the South African energy minister, Dipuo Peters, and the US energy secretary, Steven Chu, signed a nuclear energy co-operation agreement in Vienna in September 2009 while attending a conference of the IAEA.[41] Pebbles containing 9,6 per cent enriched uranium manufactured by NECSA have been sent for testing to the Idaho National Laboratory.

Given the severity of the global financial crisis and other factors, the delays in finalising the South African PBMR project have been extended further into the future. This places the PBMR Company's edge at risk. Although it emerged at roughly the same time as the Chinese model, it is likely that the demonstration plant will not go critical for at least another 9–13 years, if at all. This is likely to mean that a period of experimentation will be necessary and only then will commercial production be possible, deferred even further into the future. The claim that the South African PBMR will be the 'world's first successful commercial generation IV reactor',[42] as asserted by Dr Regis Matzie, senior vice-president and chief technology officer of Westinghouse (which has a 15 per cent share in the PBMR Company), is therefore open to question.

HISTORY AND DEVELOPMENT OF SOUTH AFRICA'S PEBBLE BED REACTOR

Early origins

With the winding up of its bomb programme in 1990–1991, South Africa became the first country in the world to renounce its nuclear weapons. President de Klerk made this public in March 1993, simultaneously announcing that the archives of the programme had been destroyed. This shielded the one thousand people who had been part of the programme from any future retribution. Indeed, those involved in the manufacture of weapons of mass destruction were never regarded as eligible to account for their actions at the TRC under Archbishop Desmond Tutu. The TRC focused on investigation gross human rights violations against individuals, granting amnesty to those perpetrators who admitted their guilt and provided information on their acts of violation to the Commission in public hearings.

Without the documentation, and without the imperative of accountability, it is almost impossible to trace the career trajectories of all those involved in the programme after it was closed.

We know that institutions like Armscor (now Denel), the South African Defence Force (SADF) (now South African National Defence Force – SANDF) and the AEC (now NECSA) reabsorbed some personnel. We also know that some found employment in an arms and explosives factory in Namibia.[43] Some of the bomb makers ended up in academia, as professors of engineering, for example, at the University of Pretoria.[44] One group of disgruntled former employees tried to sue the state for enormous golden handshakes, but their litigation failed, as they would have been jailed for flouting secrecy clauses in their contracts.[45] Others became embroiled in clandestine nuclear arms trafficking networks such as those set up by A Q Khan.[46]

Table 1: Current development of high-temperature reactors

Country	Institution	Design	Powering	Timetable
USA[32]	MIT	MPBR, 250MW$_{th}$, 120MWe, modular, intermediate heat exchange	Electricity, heat	Still in design phase
USA[33]	General Atomics	Gas turbine modular helium reactor, GT-MHR, fuel in graphite blocks, not pebbles	Electricity, heat	Not available
USA[34]	Idaho National Laboratory	'Next generation' nuclear plant, helium-cooled VHTR	Electricity, hydrogen co-generation, heat	$1.25 bn authorised, completion between 2013 and 2020
USA[35]	Adams Atomic Engines	Nitrogen used as coolant	Space, polar, underwater	Not yet developed
China[36]	Huawei/Chinergy and Institute for Nuclear and New Energy Technology, Tsinghua University	HT-10, 10MWth, then HTR-PM at 250MW$_{th}$ or 100MW$_{e}$	Electricity, hydrogen, heat	Pilot HT-10 completed 2003; first HTR-PM ready 2013, then another 30 by 2020
Netherlands[37]	Romawa	Nereus, 24MW$_{th}$	Shipping	Not yet developed
South Africa[38]	PBMR Company	PBMR DPP-200, modular, 80MW$_{e}$	Heat, electricity	Pilot plant not likely to be running until 2018–2023
Japan[39]	Japan Atomic Energy Research Institute	HTTR, 30MW$_{th}$	Heat, irradiation of materials	Criticality reached 1998

Sources: *Corporate and other relevant websites – see endnotes (accessed 30 September 2009).*

The residue of committed nuclear scientists and engineers were keen to remain active in their field. Yet, in view of the end of the bomb programme, they needed other projects to maintain their careers. Some remained within the fold of the AEC, which was then experimenting with a technique to enrich uranium through the application of laser technology (MLIS). If the AEC could find a way to crack the technology at lower cost, it felt it could provide a competitive global technology. In the end, however, the project was defeated by high costs and the closure of the conversion plant at Valindaba, which had provided the necessary uranium hexafluoride, the process gas for MLIS.

Other nuclear engineers felt that they could survive in their professions by hitching their wagons to the development of a small high-temperature reactor. Arguing that the transitional state would not be likely to invest in further PWRs due to their high cost and the need to spend on other social priorities, this group took practical steps to consolidate their expertise around developing the PBMR.

This came at a time when the future of the South African nuclear industry hung in the balance. It was clear that the extensive enrichment facilities were no longer needed for generating weapons-grade uranium. Furthermore Eskom had long regretted being boxed into an agreement to take AEC nuclear fuel for its Koeberg reactors, when the same material could be sourced very much more cheaply on the open market. The AEC took steps to decommission its enrichment plants, as well as its conversion plant, and sold the equipment at the fuel fabrication facility (called BEVA)[47] to China. The employment complement at Pelindaba was considerably downsized.

> The new state flirted behind closed doors with the industry's remnants

The ANC was also on a policy cusp. In exile, the organisation had tracked the acquisition by South Africa of nuclear expertise, declaring its opposition to Koeberg and apartheid's nuclear weapons programme. However, on coming to power, there were countervailing pressures on the new state. On one hand, there was a growing environmental and anti-nuclear lobby, emerging from affected urban and rural black communities, white middle-class activists, and trade unionists principally in the mineral-energy complex. On the other hand, there were the possibilities offered by the MLIS and PBMR technologies, which would allow the state to retain claims to being a serious global player in the sphere of nuclear technology.

In the run up to the change of power in February 1994, the environmental lobby, including the ANC Western Cape Science and Technology Group, with some confidence hosted a Conference on Nuclear Policy for a Democratic South Africa.[48] In general the tenor of the conference stressed the need to unravel the history of nuclear proliferation, to end wasteful use of resources,[49] and to assess the utility of the nuclear energy industry in relation to reconstruction and development.[50] Among the arguments raised was the redirection of human capital in the nuclear industry towards becoming a body that would end its interests in the nuclear fuel chain and devote itself to the generation of developing clean technologies. The members of the ANC and its alliance partners also called for the mothballing of Koeberg until a clear enquiry had been launched to assess the full costs of the nuclear energy programme.[51] The industry itself recognised that it would need to restructure itself to meet certain niche needs (filtration technology for the mines, medical isotopes, etc.) and become fully commercial and less of a financial burden on the state. This was embodied in the AEC's 2000+ Plan for ensuring its survival.[52]

As the policy debate unfolded the new state flirted increasingly with the industry's remnants behind closed doors and in an atmosphere of secrecy that emulated past apartheid practice.

Some of the nuclear engineers from the bomb programme had found employment from 1989 in the Pretoria-based Integrated Systems Technology Holdings (Pty) Ltd company (IST), which provided electronic systems for Armscor, the state-owned military procurement enterprise. One of these, Dr Johan Slabber, had taken a personal interest in high-temperature reactors, and, the previous year, had visited the father of the German HTR, Prof Rudolf Schulten, at the University of Aachen, to discuss the viability of applying the technology in South Africa. After joining IST, Slabber persuaded the company to propose the idea of a 5MWe pebble bed reactor to Eskom to serve remote inland sites. Slabber was also able to canvass Armscor into commissioning IST to come up with a design and feasibility study for a pebble bed-type reactor to power nuclear submarines.[53] By 1993, when Armscor money fell away, the proposal had reached a point whereby IST could offer development of the pebble bed reactor to Eskom.

Over to Eskom

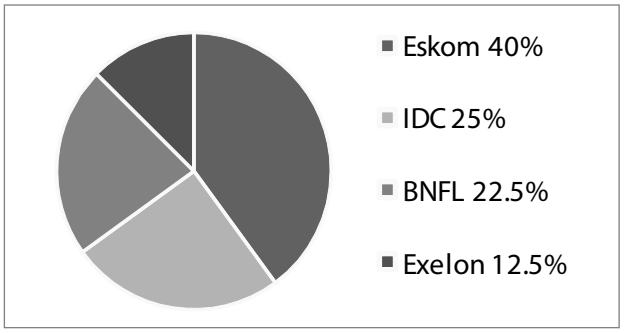
During the following five years, Eskom took increasing control of the project. In July 1995, it appointed IST to

undertake a series of feasibility studies, which were completed by April 1997. After considering and then rejecting a joint venture agreement with IST (in which Eskom held 51 per cent), Eskom ended up preferring a contractual relationship with IST and granted its nuclear division a R260 million contract to develop the PBMR design.[54]

By 1998, Eskom's Council had formally accepted that the PBMR was a priority project.[55] In 1999, Eskom formed the Pebble Bed Modular Reactor (Pty) Ltd (PBMR Co.) which it initially owned in full. Gradually, to spread risk and technology access, Eskom hoped that other companies, parastatals and government would take up shares relative to their respective contributions to the company on the basis of a subscription agreement. The preferred subscription-based holdings were offered to the parastatal Industrial Development Corporation of South Africa Ltd (IDC), US-based nuclear reactor operator company Exelon and the British Nuclear Fuels Ltd (BNFL), which was a major owner of nuclear reactors in the UK (see Figure 1).

By 2003 BNFL was close to bankruptcy and it ceased further payment to Eskom. Eskom was hoping that having nominal foreign ownership would pay dividends later, in the form of assistance with commercialising, exporting and dealing with regulators in other jurisdictions.[56]

Figure 1 Investors in PBMR (Pty) Ltd, early 2002[57]



Source: *David Fig, Uranium road, 2005.*

Note: Eskom had previously owned 100 per cent of the company, but decided to diversify. Its plan was to retain 30 per cent and grant 10 per cent to a black economic empowerment company, but this never occurred.

In policy terms, the nuclear industry was moving beyond official declarations, despite claiming to have government buy-in for the study project from 1995, and approval of the feasibility study by 2000.[58]

However, in reality, the policy process was more complex. The Mandela presidency was noted for its commitment to participatory and transparent policy making processes. These were marked by multi-stakeholder involvement, wide public canvassing of opinion, patient consultation and inclusivity. These principles also applied to the formulation of energy policy. In 1996, the DME hosted a multi-stakeholder Energy Summit outside Johannesburg. To this it invited members of concerned and affected communities, who received additional briefings on the content of the summit and how to intervene in the discussion process. Nuclear technology was not rejected outright, but the state accepted that it would only proceed under specified conditions. In the White Paper on Energy Policy, published in 1998, two years after the Energy Summit, the section on nuclear energy was worded as follows:

> Whether new nuclear capacity will be an option in the future will depend on the environmental and economic merits of the various alternative energy sources (para 7.2)… Government will ensure that decisions to construct new nuclear power stations are taken within the context of an integrated energy policy planning process with due consideration given to all relevant legislation, and the process subject to structured participation and consultation with all stakeholders (para 7.2.4)… Governance systems within the nuclear sector evolved under strategic conditions, which required great secrecy, as a result of which integration with other energy sectors was minimal. Given the nature and outcomes of past nuclear policy formulation processes, transparency and participation in nuclear sector governance will be ensured to restore public confidence in government's nuclear energy policies (para 7.2.10).[59]

In addition the White Paper undertook to review the economics of Koeberg, address nuclear safety, create policy on nuclear waste management, restructure the role of the AEC and revise the law, which until that stage included promotion and regulation functions of nuclear energy in a single Act. Mention was made about the feasibility studies on the PBMR, but the document contained no commitment to build.

It seemed, therefore, that Eskom assumed it had the relative autonomy to pursue the project, despite the fact that it was clear that the broader plans of the state and its planning processes were far more circumspect. Although the summit seemed to promise that nuclear development would only occur once there had been integrated energy planning, nevertheless Eskom was continuing with its plans to roll out the pebble bed reactor. The cart was preceding the horse with impunity.

Eskom could do this without much of a challenge, since it had the full backing in these matters of public enterprises minister, Alec Erwin, who assumed the public enterprises portfolio, under which the utility fell, in May 1999. Erwin was a strong champion of the PBMR and the nuclear industry in general. A forthright man with robust convictions and a keen intellect, Erwin also had presidential backing. It was difficult for others in government to gainsay Eskom's decisions. In any case,

few questioned the prospects of the PBMR, its budgets, or its technological experimentation.

Withdrawal and search for new partnerships

The optimism with which the PBMR project was promoted foresaw that foreign investment would play an important role in commercialising the reactor for export. It therefore came as a great shock when US-based Exelon decided to withdraw from the project in April 2002. It is uncertain whether its full investment ever matched 12,5 per cent of the company's stock.[60]

What motivated this withdrawal? According to the PBMR Company, this was due to a 'change in strategic direction' of Exelon.[61] PBMR CEO Dave Nichols stated:

> We are looking forward to their continued involvement in the balance of the detailed feasibility phase.[62]

However, the PBMR lost the possibility of Exelon, which was the largest nuclear utility company in the US, championing the passage of the PBMR's safety design specifications through the US nuclear regulators.

Exelon co-chief executive John Rowe had a somewhat different take on the reasons for disinvestment. He claimed that Exelon had pulled out because 'the project was three years behind schedule and was too speculative'.[63]

A further possibility was that the US Nuclear Regulatory Commission (NRC) had begun to ask important questions about the core temperatures in the PBMR, which Exelon was not cut out to answer.[64] During Exelon's initial approach, the regulator had raised concerns about the fuel fabrication process and control room design.[65] Mr D A Powers, a member of the NRC's Advisory Committee on Safeguards, stated in October 2001 that the PBMR was seriously flawed, since the chaotic and unpredictable movements of the pebbles inside the reactor vessel were a prescription for core instability. Powers also noted that Chernobyl had demonstrated the potential flammability of graphite, the substance used to coat the pebbles and the inside lining of the PBMR reactor vessel.[66]

The approval process was halted in the wake of Exelon's disinvestment. Without NRC approval of the design, it is impossible for the PBMR to find a market in the US. This is a key issue in view of the rival development of HTRs in the US (see the section on the emergence of HTRs on page 9) and because many countries will want to see accreditation by developed countries' regulatory bodies before making a committment to purchase.

Having lost Exelon as a partner, Eskom became even more reliant on its only other foreign investor to provide the project with some international credibility. Originally the partner was BNFL, the state-owned company that was not privatised like the rest of the British nuclear industry in 1996. This may have been because the operating and decommissioning costs of Britain's oldest reactors and troubled reprocessing plants would not produce profits for private investors. By 1999, BNFL had acquired Westinghouse, a US-based company that had been responsible for the construction of about half of the US's nuclear reactors. In 2005, it sold Westinghouse corporation to Toshiba, the Japanese transnational corporation, for $5,4 billion. Along with this sale went the shareholding in the PBMR in South Africa. This shareholding is now in the name of Westinghouse but is controlled by Toshiba. Subsequently minority stakes in Westinghouse were purchased by the Shaw Group (20 per cent), Ishikawajima-Harima Heavy Industries (3 per cent) and Kazatomprom, Kazakhstan's national uranium company (10 per cent), leaving Toshiba with 67 per cent.[67]

Westinghouse has proven to be no more of an active partner in the PBMR company than its BNFL predecessor, not having added further investment to the project. Strategically, however, it has purchased the nuclear division of IST, which was involved in the early feasibility studies and design of the PBMR, as well as developing the helium testing facility at Pelindaba.[68] This sale occurred in 2007 and Westinghouse used its apparent commitment to the PBMR as leverage to tender for the first orders of large-scale new generation PWRs for South Africa. However, in 2008, after considerable delays, Eskom announced that it was abandoning the tender process because of lack of finance for new PWRs. Both Westinghouse (with its AP-1000 model) and Areva (with its EPR, already in trouble in Finland and in France itself) had been possible contenders.

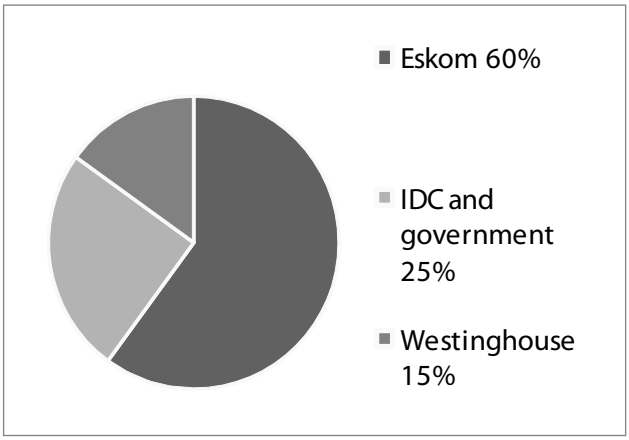
Westinghouse assisted the PBMR company in becoming part of a research team to help the US Department of Energy's Idaho National Laboratory to develop the first phase of the engineering work for a HTR.[69] More recently, Eskom has awarded Westinghouse the contract for refuelling Koeberg in the 2011–2015 cycle.[70]

Prior to the closer ties with Westinghouse, the PBMR company tried unsuccessfully to court its rival, Areva, the French state-owned nuclear company.[71] In March 2004, under pressure to acquire extra foreign investors to make up for the loss of Exelon, the PBMR company approached Areva for discussions.[72] These were continued in May 2005, when Areva officials were visiting South Africa as part of a trade delegation led by trade minister François Loos. The discussions were not definitive and did not result in Areva taking up an investment in the PBMR. Despite this, the PBMR company's general manager

denied claims arising from parliamentarians that the project was 'struggling to get international investment'.[73]

Thus investment in the PBMR company at around the time of the sale of Westinghouse to Toshiba was limited to Eskom, IDC and Westinghouse. On the PBMR company's website, only the size of the Westinghouse share is specified, at 15 per cent, down from the original BNFL share of 22,5 per cent. Presuming that some of the IDC's previous investment was taken on by government (the ratio remains unspecified), the relative investments at this time are reflected in Figure 2.

Figure 2 Investment in PBMR (Pty) Ltd in 2007[74]



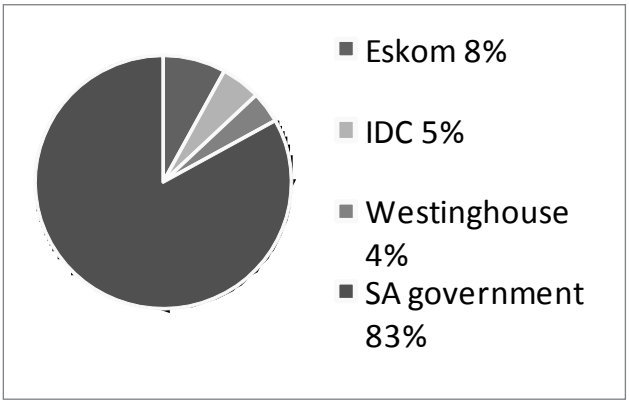
Sources: www.pbmr.com/index.asp?Content=176; http://www.energynews.co.za/web_main/article.php?story=20090806121129783

Eskom expected at that time to be a key customer for the PBMR,[75], and felt that its holding in the PBMR company should be pared down (to 5 per cent) to avoid future conflicts of interest. It argued that the state contribution should rise in order to assume more responsibility, although it is not clear through which entity. In addition, Eskom often stressed its intention to set aside 10 per cent of the PBMR company shares for a black economic empowerment partner, despite there being no specific legal mandate for this, yet nothing was ever done to put this into effect.

In August 2009, the CEO of the PBMR company, Jaco Kriek, presented a new investment profile to parliamentarians, reflected in Figure 3. This reflects a reduction of investment by all former partners and an 83 per cent investment on the part of the state, presumably through the Department of Public Enterprises. These percentages are not available in other public documents and remain to be confirmed if correct. While all previous investments were nominal and percentage ownership was not reflected in investments made, the latest configuration is likely to reflect the investments more accurately. It seems that since 2004, most of the funds devoted to the company came straight from the taxpayer.

What they signify is Eskom's increasing distance from the project. During Alec Erwin's term as public enterprises minister from 2004–2009, Eskom undertook to order 24–30 PBMRs in future, with the caveat that they should be the cheapest option at the time of the order, an unlikely prospect. During Bobby Godsell's term as chair of Eskom's board, 2008–2009, Eskom cancelled the tendering process for new PWRs and it was rumoured at the time of his departure that he was keen to review the entire PBMR project. If Kriek's presentation to parliamentarians is accurate, then Eskom has reduced its investments in the project from 40 per cent to 3 per cent. This was a further indicator that the utility was keen to shift its role from a developer and investor in PBMRs to that of a tenuous future client.

Figure 3 Investment in PBMR (Pty) Ltd in late 2009[76]



Source: Jaco Kriek, Update on the PBMR Co., 2009.

Economic viability

Despite the fact that Eskom, a state-owned corporation, has been commercialised,[77] it nevertheless has been extremely weak at financial management. For example, it has become loss making in the areas of industrial and mining tariffs and income from electricity sales abroad. This may partly be ascribed to the low prices at which Eskom charges bulk users, often in secretive contracts.[78] Poor financial planning was one of the reasons for the nationwide power cuts for some months from January 2008.[79] As a result its credit ratings slumped, and it has had difficulty raising the R385 billion it claims it needs to devote to new infrastructure to stave off future serious electricity shortages. In 2009 it announced that it had made a loss of R9,7 billion in the previous financial year.

Part of its strategy was to appeal to the National Energy Regulator (NERSA) to enable it to raise its tariffs to consumers for the period 1 April 2010 to 31 March 2013 by 45 per cent per year. Public pressures caused Eskom to revise its application to an increase of 35 per cent.[80] NERSA received a record number of objections,

including from the trade union movement and other sectors, which fear these increases will be extremely inflationary. The environmental movement has been arguing that any increases should not be granted until Eskom modifies its business model away from a stress on coal and nuclear and submits to an open process of integrated energy planning.[81] Despite the overwhelming number of objections, in February 2010, NERSA granted Eskom the right to raise tariffs by around 25 per cent per year for the following three years.[82] While punishing for consumers, the higher tariffs are unlikely to meet Eskom's need for recapitalisation and it has resorted to applying for loans of $3,75 billion from the World Bank.[83] This is also being contested by civil society organisations which argue that the World Bank should not lend money to develop the giant 4 800MW coal-fired power station at Medupi in Limpopo province, nor should it deviate from its policy of not devoting resources to the building of nuclear reactors. Furthermore there is an objection that the ruling ANC party has a 25 per cent financial interest in Hitachi Power Africa, which was granted the contract to build boilers for Medupi.[84]

Higher tariffs are unlikely to meet Eskom's need for recapitalisation

The poor record of financial management is also reflected in the runaway escalation of the costs of constructing the PBMR demonstration power plant and its fuel fabrication plant (see Appendix One).

An important nod to gaining an independent view of the viability of the pebble bed was the appointment in 2001 by the DME of a panel of experts. Their findings were supposed to be fed to the South African Cabinet so that it could make a strategic decision about the future of the PBMR. Much of the information provided to the 15 international experts arose from the Detailed Feasibility Study conducted by the PBMR company in 2001–2002. Members of the panel were given complete access to the data they required and two of them were tasked with reviewing the economic feasibility of the project. Their report was submitted in early 2002. However, after seven years this has yet to be revealed publicly and panellists were sworn to secrecy, despite their sources all being in the public domain. Findings remain with Cabinet and the DME (since May 2009 split into two separate departments, Department of Mining and Department of Energy) and these were not even disclosed to Eskom or the PBMR company. Later the then Department of Environmental Affairs and Tourism (now Department of Water and Environment, DWE) established a review panel to assess the Draft Scoping Report issued in the first environmental impact assessment process. This review has also not seen the light of day.[85]

Such secrecy is not untypical in the nuclear industry. However, it flies in the face of the culture of transparency established by the South African Constitution and the Promotion of Access to Information Act (PAIA), Act 2 of 2000. The latter attempts to realise the aim of the Constitution to afford citizens rights to official information. These rights to the DME panel of experts' report or the DEAT panel's report have not yet been exercised through application of the law.

A further instance of non-disclosure that is of importance to an understanding of the project's viability was Eskom's refusal to release into the public domain information on deliberations on the PBMR at its board meetings. In June 2005, Earthlife Africa, an environmental watchdog organisation which campaigns vigorously against the nuclear industry, was refused access by Eskom to the board minutes that it suspected would reveal Eskom's disquiet about the PBMR. Earthlife decided to litigate to obtain the minutes, as allowed by PAIA. The case was heard in August and judgment delivered in December 2005 against Earthlife with costs awarded to Eskom.[86] In an uncanny irony, Eskom's lawyers mistakenly delivered the relevant documents to Earthlife and had to approach the court to retrieve them. Earthlife was required to surrender them and had to agree not to discuss their contents.[87] However, Noseweek magazine obtained copies of the documents and has not been censured for publishing their contents, so the details now exist in the public domain.[88]

Not only has it been impossible to get an accurate picture of the full economic costs of the programme, but this has also foreclosed informed public debate on the future of the PBMR. The company has only revealed figures when asked to do so by parliamentary portfolio committees, which have the right to scrutinise the spending of public funds. Another source of information was the documentation produced by the company for the EIA process (described in the section on regulatory controls and revolving doors, page 22).[89] In general, the disclosed information has seldom been comprehensive, and always leaves room for uncertainty and speculation.

Using such public domain sources, Prof Steven Thomas, a member of the international Panel of Experts commissioned by the DME to examine the economic viability of the PBMR, has made some important observations on the inadequacy of the PBMR's financial model.[90] He claimed that documentation issued by the company 'provided almost none of the information required to assess the economic sustainability of the PBMR demonstration plant'.[91] Such an assessment would

have to be linked to the life-cycle costs of the plant, but since the demonstration plant is hardly likely to be viable of itself, it is important to examine who will absorb these costs and to what extent the commercialisation process is likely to be successful. The EIA literature provided by the company does not raise the economics of commercialising the reactor, arguing that the EIA simply applies to the demonstration plant. Thomas also notes that the (then) six-fold escalation of costs to 2004 had not offset the risk to the South African taxpayer, despite some foreign investment, and that further cost overruns were foreseen. Since it is unclear whether Eskom will be a strong customer for the project, projections offered by the PBMR rest on a series of uncertain assumptions.[92]

The EIA and the fourth design concept

The excitement of a new democratic South Africa during the Mandela presidency (1994–1999) partly arose out of great public involvement in policy-making processes. These included the Reconstruction and Development Programme, public consultation around the Constitution and various processes to introduce democratic legislation on a number of policy fronts. Inclusive multi-stakeholder public summits were held on key issues, including environment, mining, water, energy, health, land reform, black economic empowerment, labour law and education. These had a great impact on the drafting of subsequent legislation.

> There is no part of the EIA process that includes an independent review of the impact report

In terms of environmental planning, new regulations on the holding of EIAs were proclaimed. For some years the EIA regulations had been linked to pre-democratic laws. It had become necessary to update the regulations in line with best international practice and to house the regulations within new environmental legislation.

EIAs are the procedural means whereby the state engages with the public in evaluating whether proposed development projects take account of and try to mitigate environmental damage. While jurisdiction was granted to provinces over the most common types of development, more important developments (such as airports, large dams, nuclear reactors, etc.) fell under the jurisdiction of the national department dealing with environmental affairs. The South African regulations largely conform to a series of practices that have been developed internationally since the late 20th century.[93]

Essentially the EIA is conducted in a number of stages. The developer assigns the management of the EIA to a firm of consultants, paid for by the developer. They manage the processes of scoping the development, providing a comprehensive impact report and then conducting any further studies arising out of questions raised by the impact report. At each of these phases there is supposed to be extensive public participation and eliciting of stakeholder concerns.

There are, of course, some flaws in the process. It is seldom the case that the consultants, despite being nominally independent, support an outcome that diverges from the proposed development. EIAs address a specific development at a specific site and therefore are not able to assess cumulative impacts arising from the implementation of the original development, which may be of a scale quite different to that considered in the EIA. Many consultants are based in the engineering and science professions and tend to be inexperienced with regard to public consultation, especially under conditions applying to a developing country such as South Africa. They also tend to place more emphasis on the bio-physical impacts of development projects as opposed to socio-economic impacts. In the South African regulations, there is no part of the EIA process that includes an independent review of the impact report. The record of decision is left to bureaucrats, who may be open to industrial lobbying and forms of political pressure. Since the first democratic regulations were issued, they have been officially revised in order to 'streamline' and 'speed up' the decision-making process.[94] Some would argue that the revisions of the regulations have allowed for the watering down of more stringent approaches to environmental protection.[95]

The EIA for the PBMR was initiated in 2001 and its implementation was assigned to a consortium of companies, which included Poltech, Africon, Andersen Geological Consulting, Netrisk and Afrosearch (the last being responsible for public consultation). Some of these consultants had undertaken prior work for Eskom over the previous 15 years, making it difficult for them to cast themselves as independent.

In practice the process they managed proved extremely flawed:

- Alternatives to the development, including a no-go option, were not considered, flouting a standard part of EIA procedures.
- No reference was made to the technical and economic problems associated with the management of nuclear waste. The excuse given was that this was a matter for the Department of Minerals and Energy.

- Attempts to consult with interested and affected parties were extremely limited, paying the minimum lip service to consultation processes. Communities in the vicinity of nuclear installations were never fully informed of proposed developments in their own languages and in a manner appropriate to their levels of literacy.
- Unlike the case in other highly contested EIAs, such as the one of the mining of titanium inside the Greater St Lucia Wetlands Park, the PBMR EIA made no provision for an independent review panel to evaluate the environmental impact report. While not a legal requirement, this would have had some role in guaranteeing the transparency of the process.
- Key parties were not permitted to comment or raise objections to the final environmental impact report, despite major changes to the document since its original drafting.[96]

Notwithstanding these and other content and procedural flaws, the Director-General (DG) of the DEAT, Dr Crispian Olver, issued its record of decision in June 2003, declaring that the EIA was 'acceptable' and compliant with legal regulations. However, this spurred civil society organisation Earthlife Africa, one of the key objectors to the development, to take legal action to secure its right to be heard in the process.

Technical assessment of impacts of a specific design configuration are not possible as part of the EIA

Ultimately the Cape High Court felt that the DEAT had taken its decision prematurely, and, calling it 'fatally flawed', ordered the department to provide an opportunity to Earthlife and other interested parties to submit further representations to it before it issued a legally valid record of decision. While the judgment of January 2005 restored a degree of fairness to the process, it did not pronounce on Earthlife Africa's substantive content objections to the PBMR.

The judgment also required that the DME had to produce a national policy on nuclear waste before the DEAT could issue a record of decision on the EIA. Despite the fact that nuclear waste had been generated since the 1940s, until 2005 no policy existed with respect to its management. The DME set about formulating a policy, which, in its final version, failed to pronounce definitively on the question of managing the country's high-level nuclear waste (spent fuel, depleted and bomb-grade uranium).

The Cabinet agreed to abide by the rule of law and accepted that there had been some irregularities in the EIA procedurally.[97] Yet, the response of Eskom and the PBMR company, as applicants, was not to correct the flaws in the existing EIA, but to launch an entirely new process. Its argument was that the design of the PBMR had been modified substantially and its output was now 400MW thermal or 165MWe, some 50 per cent larger than the first configuration of 110MWe. Based on the design modifications introduced in 2003, the second iteration of the EIA, covering the reactor's fourth design, was still under way at the end of 2009.

Fifth design concept

One of the ironies of the EIA processes undertaken for the PBMR is an obvious one: how can we measure the impacts of a development without having the design of the development in place? This issue has entirely been dodged by a contrived arrangement, agreed to by officials of the DEAT (now DWE) who convened a meeting of the relevant government departments to try to settle the dilemma. The resulting memorandum stated that the design specifications of the demonstration plant would not be considered by the EIA, but rather by the licencing process conducted by the National Nuclear Regular (NNR). In other words, the public would not be allowed to concern itself with the design of the reactor during the course of the EIA. Public questions and objections have since been deflected by the consultants, who refer to the licencing procedures which are not in the public domain. This means that technical assessment of impacts of a specific design configuration are not possible as part of the EIA. This chicanery flies in the face of the principles of environmental justice contained in chapter 2 of the National Environmental Management Act (NEMA), Act 108 of 1997. NEMA is the framework legislation covering environmental management, and was crafted through a participatory process during the period 1994–1996. It is the same act under which the EIA regulations fall.

The argument offered to justify this position is that the development will be built to comply with NNR licencing requirements and that therefore the design specifications are irrelevant. However, while the reactor may be built in order to comply with these requirements under normal circumstances, an EIA for a nuclear facility needs to be able to assess what will happen when the technology is under stress, say during a worst-case accident.[98] The matter is one for legal determination.

And although the second EIA was initiated to reflect a change of design (to 165MWe), we are faced with a second

irony. In February 2009, it was announced that there was to be a fifth essential shift in design. No longer would the PBMR demonstration plant be generating 165MWe, but only 80MWe, as well as 200MW of heat. Its purpose is no longer exclusively the production of nuclear power, but also of heat, in order to feed this into chemical and other processes. The PBMR is also being seen in terms of being able to generate hydrogen as a fuel for future vehicles, or to be used in the desalination of sea water.

The fifth design of the PBMR is therefore not just a rescaling of previous designs to produce more output, but is a transfiguration of the original purpose of the reactor. Surely, if the reactor has undergone such a fundamental design change, the technical assessment of its predecessor design is now somewhat irrelevant? Had the PBMR company been serious about the EIA at all, it would have announced that a third EIA process was necessary to reflect the major changes in the design.

There is a further set of ironies. Although the NNR has never received a licence application for the technology, and although the EIA for the previous design (however flawed) has not yet been pronounced upon by government, the PBMR company has already granted important sub-contracts to engineering firms for parts of the technology (see Appendix 2). When questioned, the PBMR company has argued that it is not in violation of EIA regulations because none of the sub-contracts has resulted in any equipment being placed on site. This

Box 2: Nuclear governance in South Africa

Inter-Ministerial Committee on Energy (established 2009)
- Chaired by public enterprises minister
- Includes Treasury, the Presidency, and the departments of public enterprises, energy and economic development
- Developing a 20-year Integrated Resource Plan
- Focuses on facilitating long-term security of supply, cushioning the impact of increased electricity tariffs on the poor, ascertaining the macroeconomic impact on global competitiveness, demand side management, nuclear power and renewable energy.

Department of Energy
- Manages the Nuclear Energy Act
- Sets broad energy policy, nuclear energy policy and nuclear waste management policy
- Responsible for NNR
  - licences and inspects all nuclear facilities
  - protects public from exposure to radioactivity
- Responsible for NECSA
  - runs research at Pelindaba, North-West Province
  - runs nuclear waste disposal site at Vaalputs, Northern Cape
  - commercialises applications of nuclear energy
  - site for manufacturing of fuel (pebbles) for PBMR
- Responsible for NERSA
  - sets tariffs for electricity sales
  - issued document analysing 2005/2006 closure of Koeberg
- Co-ordinates National Electricity Response Team to deal with electricity supply

Department of Public Enterprise
- Responsible for Eskom Holdings Ltd
  - operates Koeberg nuclear power station
  - developer of proposed Nuclear-1 and subsequent large reactors
  - investor in PBMR (Pty) Ltd
  - Koeberg site of demonstration plant of PBMR
- Responsible for PBMR (Pty) Ltd

Department of Water and Environment
- Oversees and evaluates national EIAs
- Issues a record of decision for each EIA application

National Treasury
- Responsible for budgeting and allocation of finance

Department of Trade and Industry
- Issues industrial policy action plans
- Convenes Council for the Non-proliferation of Weapons of Mass Destruction
- Responsible for Industrial Development Corporation
  - investor in PBMR (Pty) Ltd

Department of Higher Education
- Promotes university-based nuclear research

Department of Science and Technology
- Incentivises research and development

Department of Labour
- Compensation Commission arranges monetary compensation for victims of occupational disease (e.g. Pelindaba workers)

Parliament
- Each department has a counterpart parliamentary portfolio committee in the National Assembly, which exercises some oversight on its workings
- Select Committee on Public Accounts oversees government spending
- National Council of Provinces exercises oversight through Select Committees

Auditor-General
- Provides financial oversight for public sector entities

is another case of the PBMR company pre-empting the outcome of the EIA process and acting with impunity rather than obeying the rule of law.

The contract for the fuel plant is already under way. The others await final approvals. However, the anticipated income for the sub-contractors has had to be deferred indefinitely.

Will we ever see a demonstration PBMR?

It is still unclear whether the demonstration plant will materialise. The PBMR company has already swallowed up R8,47 billion, mostly of taxpayers' money.[99] Without further state support in the pipeline, the company, as predicted, had run out of funds to continue operating on the same scale by March 2010, retaining only 200 of its 800 staff and three of 11 managers.[100] Since it has failed to tap Treasury for further grants, it will need to contract loans on the open market, or seek partners (like Westinghouse) to inject direct investment, if it means to survive. These options are very unlikely to materialise.

Eskom is turning towards the idea of building new-generation PWRs

The question of whether the state agrees to support the project through thick and thin, or cut its losses, was finally resolved after the release of the 2010 Budget. It is likely to be confirmed in further decisions on the future of the nuclear industry to be taken in August 2010.

The arguments for ditching the PBMR are compelling. First, each unit will not be able to deliver very much energy and therefore the project does not fulfil its early promise of assisting the nation to fill its energy gap. Instead, Eskom has begun to turn more decisively towards the idea of building new-generation PWRs at sites identified in the 1980s. Second, the PBMR might be in a position to generate heat for industry, but most industrial and existing thermal power plants generate immense amounts of waste heat anyway. The technology for capturing and applying this waste heat locally may cost only a fraction of that of a PBMR. Third, South Africa has a rather precarious energy budget, with Eskom desperately attempting to raise funds through cuts, higher tariffs and loans. It is unlikely that the PBMR will alleviate this problem; rather, it would add considerably to infrastructural costs and intensify the national debt. Fourth, there is no guarantee that the fifth redesign is the final one or that there is any definite date for finalising the EIA, the licencing process, or the construction of the demonstration plant. Projections keep being revised and postponed deeper into the future. As a result, order books are empty.

The PBMR company is also recognising that it can no longer claim to be any definitive answer to the country's energy needs. As such it is seeking to find an alternative role ('rebranding') for its services. CEO Jaco Kriek has gone on record as suggesting that the PBMR company be restyled as Eskom's nuclear division. This is an option, but an unlikely one in view of Eskom's increasing distance from the PBMR project. The nuclear industry feels that the company will restructure itself as a nuclear engineering design facility.

The question thus remains: what does South Africa do with its nuclear engineering human capital? If this problem had been addressed from 1994, we might have come up with a much more creative solution, such as redirecting scientists towards more socially useful projects aimed at resolving South Africa's developmental priorities. Without such solutions, it is likely that the country will lose many of its nuclear scientists to other countries, owing to a global shortage of such personnel.

REGULATORY CONTROLS AND REVOLVING DOORS

The National Nuclear Regulator

It should be mandatory for every country with nuclear facilities to install a nuclear regulatory authority. What is interesting in South Africa's case is that no such body existed prior to 1988. This at least 40 years after the creation of a uranium mining industry and the AEB, whose brief included the conduct of nuclear research. It occurred well after the start up of the SAFARI-1 reactor at Pelindaba in 1965, the two power reactors at Koeberg and of a waste dump for low- and intermediate-level nuclear waste by 1984.

Prior to 1988, the operation of reactors was governed by the licencing branch of AEC (successor to the AEB from 1970). While licencing is an important part of the regulatory process, a full-scale regulator has to monitor a much wider range of contingencies.

Because this intra-industrial licencing process ran against global practice, the government of the day decided to carve the licencing branch out of the AEC and declare it to be the new regulator. Between 1988 and 1999 it was known as the Council for Nuclear Safety (CNS). During this phase the mandate of the CNS was granted under the former Nuclear Energy Act, Act 131 of 1993. This meant that the same piece of legislation covered the regulation as well as the promotion of the industry.

Even the management of the CNS found this situation untenable and began to lobby for a discrete piece

of legislation to provide for regulation. The outcome of this process was a recrafting of the legislation. In 1999, Parliament passed the National Nuclear Regulator Act, Act 47 of 1999, which came into force in February 2000 and turned the CNS into the NNR. A new Nuclear Energy Act, Act 46 of 1999, promoted nuclear energy, established NECSA (the former AEC) and took on responsibilities for non-proliferation and the control of uranium. Responsibility for both Acts was placed in the hands of the DME. Since May 2009, this department has been split, and the Acts are now implemented by the successor Department of Energy.

Part of the governance problem has not been resolved. Although the regulatory functions have been placed in a separate Act, the energy minister now has political responsibility for both promotion and regulation of the industry. This may present a conflict of interest for the minister when s/he is in a position to decide between promotional and regulatory priorities. This could create a problem for democratic governance in the sector. The NNR should have been granted more independence, falling under a different department, or even becoming a chapter nine institution under the South African Constitution. This would have removed the potential for any conflict of interest.

> A revolving door was created between the industry and the regulator

The NNR operates under both budgetary and human resources constraints.[101] Together with its limited political leverage, this has made it extremely difficult for it to take on the well-entrenched and powerful mining industry, with its huge legacy of indiscriminately depositing radioactive waste in the form of mine tailings and slurries in the Witwatersrand and other uranium mining areas. Under enormous public pressure, it has only since 2007 teamed up with the Department of Water and Environmental Affairs in addressing the massive contamination of the Wonderfonteinspruit, a tributary of the Vaal river on the West Rand, by establishing a national steering committee to implement a remediation action plan.[102]

The NNR's record with respect to transparency and openness has been somewhat spotty. As the CNS it had tried to reach out to some of the key stakeholders concerned about nuclear energy in South Africa. Despite its mandate to include representatives from labour and affected communities on its Board, it acted very slowly in doing so. Until late 2003, it had appointed a former Eskom employee as its community representative, despite many approaches from civil society denouncing this person as an illegitimate spokesperson for community interests. Only after this did the NNR advertise the position in such a way as to attract a representative from affected communities. However, the voices of the community and labour representatives have not carried huge weight in the Board.

On other occasions the NNR had been scrupulously neutral. It had, for example, in 2005, managed to confirm Earthlife Africa's claims that an unsafeguarded calibration centre was emitting radioactivity on private property outside the Pelindaba facility. This was affirming, given the attitudes of the then president and deputy president, who had accused Earthlife of scaremongering, and threatened to curb the rights of alert watchdog organisations.[103]

However, the NNR's reputation for neutrality has not survived. The fatal flaw was the appointment of Maurice Magugumela, a former safety and licencing manager of the PBMR company, as the CEO of the NNR, formally beginning on 1 April 2005. The appointment was made by the then minerals and energy minister, Ms Phumzile Mlambo-Ngcuka, over the heads of the NNR board members in clear violation of the NNR Act,[104] and later given full Cabinet approval. In doing so, the minister was creating a revolving door[105] between the industry and the regulator, at a time during which the regulator needed to be seen as scrupulous in its impartiality and rejection of special interests.

Ironically the NNR was to act against the PBMR company soon after Magugumela's appointment. In October 2006, the NNR found out that certain activities relating to the manufacturing of components for the PBMR demonstration reactor had started. This was a violation of the NNR Act. The NNR then directed the PBMR company, through Eskom, to suspend all such activities until corrective actions had been taken, including the review of all technical documents and full monitoring. This suspension lasted until December 2007, by which time the NNR was satisfied that the PBMR company was compliant. Material produced before the lifting of the suspension remained under quarantine at the respective PBMR suppliers and will only be released on a case-by-case basis when ready for installation.[106]

Magugumela served for three years as the CEO of the NNR and was replaced on 1 April 2008.[107] During his term of office there was a marked downturn in the release of information to the public. Specific public requests for information from the NNR remained unanswered.[108] Instead, members of the public were referred to the cumbersome procedures of PAIA. In theory PAIA should have made it easier to obtain official information; however government bureaucrats have tended to delay compliance and so frustrate the requests.[109]

The South African History Archive (SAHA) and Earthlife Africa submitted numerous requests for information to the NNR under PAIA. These included records relating to worker safety in the industry, licencing of nuclear facilities, nuclear waste management, technical safety, complaints about occupational health and NNR board minutes.[110]

SAHA experienced great difficulties accessing this information and in February 2006, met with the CEO of the NNR who provided assurances of co-operation. Outstanding requests were resubmitted, yet it took a further meeting with NNR in August 2006 for a number of requested reports to be released.

Regarding the management of nuclear waste, an inspection visit to the Vaalputs radioactive waste disposal facility noted 55 violations of the licence and this caused the NNR to close the facility in September 1996 until the AEC, which operated the facility, was in compliance. It was discovered that the AEC failed, among other things, to implement quality controls and training programmes, to develop emergency planning, to maintain records, to control radioactive effluent, to maintain personnel radiological protection, to check instrumentation and to audit

> Drums full of nuclear waste were not adequately stored

safety procedures. Even worse was the realisation that the process of storing the drums full of nuclear waste (the main task of the Vaalputs facility) was inadequate and that there were no arrangements to store or retrieve records on the disposed waste. The AEC was accused of a general lack of management and supervision at all levels and had no effective mechanism of complying with licence conditions.

This document took a full decade to reach the public domain.[111]

The NNR is supposed to safeguard and protect the public from exposure to ionising radiation emanating from the nuclear industry. If it continues to make it difficult for the public to gain access to the information on the industry that is necessary to secure its rights and safety, then the question has to be raised: who guards the guardians? Can parliamentary portfolio committees be relied upon to question the NNR, or are MPs too constrained to challenge parts of the executive? What measures will the public have to take to ensure that the NNR really acts in its interests?

Revolving doors and conflicts of interest

Eskom CEO and IST

In 1997, Eskom appointed a new CEO, Reuel Khoza. Khoza was a high flyer in the new Black economic empowerment (BEE) economy, holding a dozen corporate chairs[112] and 20 corporate directorships.[113] Having a solid academic background in psychology and business studies, he was also an entrepreneur in his own right. He chaired his own companies, AKA Capital and Co-ordinated Network Investments. Khoza also served on the executives of the Institute of Directors, Black Management Forum, World Business Council on Sustainable Development, NEPAD, the President's Investment Council and the South African Institute of Management and was an economic advisor to ASGISA.[114] Despite his busy business life, he had apparently been persuaded by president Thabo Mbeki and other influential Cabinet ministers to take on the challenge of chairing Eskom as part of his 'national duty'.[115]

What was material in the story of the pebble bed was his simultaneous directorship of IST Holdings. IST was forged by a nuclear scientists and engineers active in the South African bomb programme, and was an early partner to Eskom in carrying out some of the design functions of the PBMR. Soon after his appointment to chair the Eskom board, Khoza established the private Co-ordinated Network Investments (CNI), which, in turn, owned AKA Capital, another of Khoza's investment vehicles.

When IST Holdings' controlling company, the IST Group, was listed on the Johannesburg Securities Exchange (JSE) in September 1998, Khoza ceased to be a director. However, he maintained a strong connection with the company, since his CNI held 29 per cent of IST's share capital at the time of issue. In March 2002, AKA Capital bought 11 million IST shares as part of a BEE deal. This brought Khoza and his associates' holdings of IST to 32 per cent, because of CNI being in control of AKA Capital. He was clearly well poised to strengthen the IST-Eskom link. When, in August 2003, IST gained its single biggest contract worth R260 million to design the PBMR, Khoza stood to benefit considerably.

This benefit was augmented when IST delisted from the JSE in October 2004, when the group was acquired by an investment consortium. Khoza and his associates were paid out a sum of R80 million from the shares formerly controlled by CNI.

NNR CEO and IST

Louisa Zondo was appointed as CEO of the NNR in 2001. Her term of office ended in November 2004. A month before leaving the NNR she took up a non-executive directorship on the board of IST. This was

due to her private involvement in a company called ICT Investments, which was busy becoming a BEE partner of IST, and which came to hold 25 per cent of the IST group. Ms Zondo had been appointed by a friend from her school days, Xoliswa Kakana, who headed ICT.

Perhaps her simultaneous service on the boards of NNR and IST was overlooked by the NNR and the responsible minister, because Zondo was due to depart the NNR. However, there was little attempt to respect the ethical boundaries. This was especially the case since it would be the NNR that would have to licence the PBMR technology.

The march of the directors-general

Revolving doors have been noticed in the following cases:

- Dr Alastair Ruiters, former DG of trade and industry, served under former minister Alec Erwin, a great advocate of the pebble bed programme. He was, while still DG, appointed to chair the PBMR company in 2004 and continues to do this. Ruiters is now involved in BEE companies in management and extractive resources, being CEO of Sediko Holdings.
- Dr Rob Adam, former DG of science and technology, is currently CEO of NECSA.
- Roger Jardine, also a former DG of science and technology, is now CEO of Aveng (formerly Anglo-Vaal Engineering), a JSE-listed company which formed a consortium with Areva, the French state-owned nuclear reactor builder, to bid for Nuclear-1, South Africa's next conventional reactor. The bids were cancelled by the state for lack of finance in December 2008.[116] Jardine said Aveng was 'disappointed' by the cancellation of the tenders.[117] Aveng is a member of the Nuclear Industry Association of South Africa.
- Ms Joanne Yawitch, a deputy-DG for environmental quality and protection in the department of environmental affairs has not left her post. However, she has simultaneously served on the board of the NNR. Her line responsibilities in government include the management of national EIAs. Not only has she overseen the process of 'streamlining' EIAs[118] (which some would regard as a watering down process), but she was also a participant in a co-operative agreement between NNR and the then DEAT which decided that the PBMR's EIA could be conducted without having to provide a final design. The agreement reasoned that the NNR licencing process would take care of concerns about the safety of the design. This proposition has been challenged in various submissions to the department and the EIA, among others by the Legal Resources Centre, South Africa's most famous public interest law firm.[119]

Corporate governance is often subjected to specific guidelines. In South Africa, a series of reports by the King Committee convened by the Institute of Directors[120] has played this function to a great extent. Yet in the nuclear industry, there has been a severe shortage of good governance practices.[121] This flies in the face of the need for scrupulous transparency in an industry with an inherently risky public impact. However, the industry in South Africa has continued to live up to its global reputation for secrecy, opacity and impunity. This does not bode well for the development of a culture of openness in a young democracy like South Africa.

RE-EVALUATING PRIORITIES IN A TIME OF CRISIS

Global crisis

From 2008, South Africa began to feel the impact of the global financial crisis, experiencing a decline in investment and rising unemployment of up to a million people.[122] This has had severe implications for policies aiming to reverse poverty and South Africa remains among the most unequal countries on the planet, surpassing even Brazil.[123] Obscenely high disparities of pay-scale exist between CEOs and ordinary workers, with senior management bonuses having become almost guaranteed irrespective of merited performance.[124] Whole industries like textiles and clothing are close to extinction and even the motor industry is reaching low levels of technical viability with the closure of important component plants.[125]

South Africa's energy crisis

Adjunct to the crisis of finance is an energy crisis. From 2005–2006, this began to become clear in the Western Cape, home of the existing Koeberg nuclear reactors. For various reasons, the reactors failed to work and this led to electricity shortages and blackouts throughout the province. Millions of rands of business were lost and the export fruit and wine industries were particularly hard hit as refrigeration failed. It took some months for the problems to be addressed and for electricity to be delivered in an uninterrupted fashion.[126]

The lessons of the regional crisis were, however, not absorbed by the utility, Eskom, and in January 2008, electricity shortages began to occur throughout the country. Eskom had failed to make proper provision for deliveries of coal, much of which was wet due to a very rainy summer and hence could not be combusted within the power stations. A number of power stations were closed for maintenance, lowering the margin of available excess power. Random outages became the

norm and later the outages were rationed and their times advertised. Then suddenly, by the end of March 2008, the outages ended and normal delivery of electricity resumed.

Eskom was seen as largely to blame for not challenging government's reluctance to invest in new infrastructure. Government had planned for the parastatal companies to operate commercially with a view to later privatisation. It had therefore resisted spending on infrastructure in the hope that the new private owners would take care of this. What was not well understood was the nervousness of the private sector to invest in electricity generation because South Africa's electricity prices were artificially low, leaving little room for profit taking. Traditionally prices reflected the low wages of the coal miners, the failure of the price to include externalities like pollution control and health costs and because of huge concessions granted to foreign investors investing in electricity-intensive processes such as aluminium smelters and deep-level gold mining. When investments grew after the end of sanctions, the total demand for energy increased significantly. Although the grid was extended into townships and rural areas, households were not the highest users of electricity (at 17 per cent). Bulk users tended to be the 'mineral-energy complex' identified by Fine and Rustomjee, as well as the road-dominated transport industry.[127]

> Industrial policy has not favoured energy efficiency approaches

It was to the bulk users that Eskom turned as soon as the crisis was patent.[128] They were urged to cut production from 25 August 2008 for five days, then reduce their electricity consumption by 20 per cent, while households were expected to take a 10 per cent cut in their consumption.[129]

Energy saving and demand-side management had become part of Eskom's thinking, but while electricity prices remained low, so were the incentives to economise.

The solution provided by Eskom and the state was to double the existing electricity output by adding a further 40 000MWe. This meant bringing old mothballed coal-fired power stations back into production and commissioning extremely large new ones. Open-cycle gas turbines, relying on expensive diesel imports, would take care of peak demand. In addition the state favoured the extension of the nuclear component to around half of this increase. Renewables were derided as not being cheap enough and not robust enough to deliver consistent base-load requirements.

What role was there for the pebble bed in resolving the electricity crisis? The notion of it being modular meant that units could be added one by one at a single site, in multiples of six or eight. This would have delivered, under the PBMR's fourth design, 990–1320MWe at such a site. However, with the fifth design, the PBMR is only able to provide less than half of this amount, 480–640MWe.

This now pales into insignificance in comparison with conventional reactors. Eskom began to investigate this option and announced a tendering process in which both Areva (with its European Pressurised Reactor, EPR, at 1650MWe per plant) and Westinghouse (with its AP-1000 PWR, at 1154MWe per plant) put in bids. However this process was cancelled in December 2008 when Eskom announced that it did not have the finances to purchase any reactors. The prices bid were also about double those forecast by the government. In the meantime Areva and Westinghouse remain active in their lobbying, with offers of loans, opportunities for training and promises of localising component production.

South African industrial policy

Industrial policy has tended to favour the larger users of electricity, such as the mining houses, the steel plants, the smelters and refineries and coal-to-oil conversion plants. Incentives are still provided to some industries, such as motor, textile and clothing manufacture. Industrial policy has for the most part not taken into account the need to decarbonise the economy, nor has it favoured energy efficiency approaches. Instead of better planning and incentivising adaptation towards smarter and greener industrial expansion, it continues to emphasise traditional approaches and expects the energy utility to meet the resulting increased demand for energy.

A case in point is the Coega smelter. Coega is an export processing zone and harbour close to the Port Elizabeth/Nelson Mandela Bay metropole. In the controversial arms deals of the 1990s, one of the offset projects offered by the German steel company, Ferrostaal, was to build an aluminium smelter at Coega, based on offers of extremely cheap electricity. Ferrostaal's smelter was regarded as the 'anchor' project, the one that would attract downstream and other industries to the Coega complex. The electricity demanded by the smelter would have doubled that already consumed in the area. It should be noted that South Africa produces no bauxite, hence all the raw material for the smelter would have had to be imported. The value added locally was in the form of cheap electricity and a licence to pollute outside the more stringent jurisdictions of the North.

Ferrostaal was unable to deliver and the contract to build the smelter passed to Pechiney, which in turn was absorbed in 2004 by Alcan, which in 2007 was purchased by Rio Tinto. Eskom had offered to provide the smelter with a dedicated transmission line and furnish electricity at a rate that was so cheap that it still remains secret. Since the energy crisis of 2008, Rio Tinto Alcan has removed its staff from the Coega project and placed the project on ice. Coega, in losing its 'anchor' project, is looking more and more like a white elephant.

Instead of developing smart strategies to address 21st century problems, South Africa's industrial planners have not begun to think outside the 20th century box. Under President Zuma, a new Ministry of Economic Planning has been created, with a former trade union official, Ebrahim Patel, as minister. However, this ministry is still trying to find its feet and in planning terms may lose out to a more powerful and orthodox planning commission located in the Presidency, led by the former finance minister, Trevor Manuel. Mired in conflicts, it seems unlikely that either body can ensure that South Africa can 'leapfrog into the solar age', as Wolfgang Sachs recommended at UN world summit on sustainable development in Johannesburg in 2002.[130]

> Local scientists are dependent on corporate contracts

The Department of Trade and Industry in February 2010 issued the second Industrial Policy and Action Plan (IPAP2). This has placed some stress on 'green' jobs in the renewable energy sector (within a very low target set in 2002), but also talks of extending the nuclear fleet, providing incentives for localisation of nuclear services, subsidising electric cars and stabilising the market for biofuels by supporting blending initiatives.[131] IPAP2 only makes brief mention of climate change and contains insufficient discussion of the constraints that might be placed on industry by sharp rises in electricity prices. Nor does it deal with the implications of the declaratory commitments by government on the eve of the Copenhagen climate change conference in December 2009 that the country will make absolute reductions of 34 per cent below business-as-usual by 2020 and 42 per cent by 2025.[132]

This would enable South Africa's emissions to peak between 2020 and 2025, stabilise for 10 years and then decline in absolute terms. Such commitments are conditional on a fair, ambitious and effective outcome to the international climate negotiations (now deferred to negotiations in Cancún in December 2010) and on financial and technical support from the international community.

However, a further hidden conditionality is obtaining support for this process from the South African business community to comply with reduction efforts. IPAP2 will only be sustainable if energy and climate considerations are factored more significantly into industrial policy in future.

South Africa's science and technology profile

South Africa has a small but active scientific community. However there is almost no tradition of yoking this community's activities to meet the developmental needs of the poor. Instead, we find local scientists becoming dependent on corporate contracts, research agendas feeding corporate priorities, universities no longer doing independent research, and large corporate philanthropic interventions that serve private interests. Former state institutions, like the CSIR, are now private and depend for their livelihoods on securing private contracts.

The state seems to see its developmental role in line with the needs of large-scale corporate capital rather than those of the poor. For example, in the countryside, the state favours interventions by large-scale capital in the realm of agriculture, instead of first securing local and household food security and food sovereignty. The rapid dominance over national agriculture of companies like Monsanto, with their promotion of genetically modified crops, their purchase of a majority of local seed companies and their aim of pushing high-input agriculture, has been supported in a number of ways by the state. This has also been reinforced by the activities of the Gates Foundation in favour of the 'green revolution' for Africa. In fact, instead of being revolutionary, these interventions are causing greater social and economic differentiation in the African countryside, causing greater reliance on products from foreign multinationals, creating deeper cycles of debt and commercialising the commons. Greater poverty and hunger in Africa is the result.[133] Genetically modified seed is being foisted on small producers without their prior knowledge or consent. This has been happening on a considerable scale in areas like the Eastern Cape.[134]

The obsession with the 'modern' (e.g., the notion of the so-called green revolution) has not served the interests of the poor. In the same way, nor have South Africa's energy policies. The poorest find electricity unaffordable, despite a free initial allocation. Organisations like the Soweto Electricity Crisis Committee (SECC) have been established in response to electricity cut-offs. SECC aims

to reconnect illegally the many victims of electricity cut-offs whose situation results from an inability to pay.[135]

Eskom's capitalisation plans are unable to support the poor. The energy regulator recently granted an annual increase of 25 per cent of the current tariffs, meaning that the cost of electricity to consumers will rise by around an additional 100 per cent by the end of the three-year cycle. The measures suggested to alleviate the problems for poor consumers in Eskom's application are derisory. [136]

The pebble bed reactor is unlikely to be able to resolve South Africa's energy shortage in a cost-effective way, let alone ensure that electricity is more affordable for the poor. Instead its aim is to serve those industries that are already energy-intensive, without questioning whether South Africa's policy path should encourage such appetites.

Valuing the ability to harness pebble bed technology (despite its benefits remaining out of reach) is redolent of a misplaced and narrow technological nationalism. It creates a privileged position for 'our' boys and their toys. It tries to place South African science in the same league as the USA, China and Japan. But to what end? It is incapable of providing any resolution to the developmental gap that characterises South Africa. It creates little advantage in the mitigation of climate change. It would provide a small amount of expensive electricity. It would not be the first choice in any kind of open competition. It is overly costly in terms of harnessing the energies of human and other resources.

> The PBR is unlikely to resolve the energy shortage in a cost-effective way

The little prestige South Africa gains from the PBMR in terms of scientific prowess could have been enhanced so many more times if the same resources had stimulated due progress in the field of renewable energy. Instead, the PBMR has swallowed the lion's share of state energy investment money, leaving very little for the stimulation of a renewables industry.

Challenges to the nuclear renaissance

The nuclear industry likes to talk up the existence of a nuclear renaissance. It points to the revival of the fortunes of the large companies that offer the prospect of new generation nuclear reactors.

The order books for reactors dried up after Chernobyl and this situation lasted for around two decades. However, more recently, the companies that construct reactors have reported that about 50 reactors are under construction, mostly in Asia. Orders for a further 20, commencing construction between 2009 and 2017, have been reported in the USA, Argentina and Europe. Some of the new reactors will replace old ones that no longer function. For example, in the UK the total number of new reactors in operation will not exceed the number closed down.

There have been a number of problems with the renaissance. Among them are Areva's troubles in trying to build two European Pressurised Reactors (EPRs) in Finland and France respectively.[137] Construction of the Finnish reactor was initiated in August 2005, but by the end of 2009 was over three years behind schedule. This was mainly due to the discovery of safety and quality-assurance problems with the piping, containment liner and concrete base slab.[138] Areva estimates the current cost at $6,7 billion, at least 75 per cent over the original budget, and is being sued by the Finnish client.

At the French plant at Flamanville, Normandy, similar problems were found after the start of construction of the EPR in December 2007. Safety concerns temporarily shut down the site only nine months into construction. The plant is at least 20 per cent over budget and has been reported to be two years behind schedule.

The much vaunted EPR is being touted to South Africa as one of the options that could fill the order for a series of conventional reactors. Eskom has plans to locate these close to Cape Agulhas (at Bantamsklip) and Oyster Bay (at Thyspunt). Although the tender for these reactors was cancelled for financial reasons, Areva maintains an active operation in Fourways, Johannesburg and has offered financial, technical and training support to the local industry. It has contracted a private think-tank to model the macro-economic conditions under which South Africa could make use of Areva's EPR.[139] Areva's CEO, Anne Lauvergeon, has a seat on the South African President's international investment council.[140]

Areva's troubles are only one indication that the so-called nuclear renaissance is experiencing some setbacks. 2008 was the first year in the history of the nuclear industry in which no construction started on a single reactor. And in June 2008, the IAEA announced that world nuclear electricity generation had plunged by two per cent in the previous year, more than in any year since the first fission was linked to the Soviet grid in 1954.[141]

CHALLENGES TO LOW-CARBON CLAIMS

Although the nuclear industry claims that it is a low-carbon option, this argument needs to be applied in a cradle-to-grave analysis of the entire nuclear chain.

It is correct that the actual reaction does not emit carbon. However, the industry needs to look at other inputs and outputs of the chain before it can honestly claim that nuclear is a low-carbon option.

The following links in the chain are highly carbon-intensive:

- Removing uranium from its ore is one of the most highly energy-intensive forms of mineral extraction
- The conversion of uranium from a solid to a gas for the purposes of enrichment is highly energy-intensive
- The enrichment process itself is extremely energy-intensive (in South Africa, the former enrichment process at Velindaba was powered by a coal-fired power station on site that emitted a third of Koeberg's output)
- Thousands of tons of cement are used in constructing a reactor; cement manufacturing is a highly energy-intensive process
- Transportation of the nuclear fuel and waste rely on the burning of fossil fuels, as do the components of reactors and these often involve very long distances
- At the end of the life of the reactor, it needs to be disassembled and the components treated as waste requiring disposal, which involves great energy consumption

These processes are among those which are generally powered by fossil fuels, at least at present in South Africa, at a rate of 94 per cent. Should we double our nuclear fleet, this percentage will be reduced to around 88 per cent. In a country like France, the sums will be different, as around 80 per cent of all electricity is powered by nuclear. However, under South African conditions, it is unlikely that these processes will not involve the burning of coal and petroleum.

For South Africa to derive a carbon benefit from switching to nuclear power, the country would have to commission so many new reactors that the nation would be bankrupted. The benefit would, in any case, only be seen after many generations.

In terms of carbon reduction, it would be much less risky and time-consuming to switch to renewable energy sources.

DEBATE ON THE FUTURE OF THE PBMR

Since the latest design of the PBMR delivers so little energy, it cannot be argued that it can efficiently and effectively resolve our energy shortage in the medium term. Even Eskom has recognised this by beginning to consider new generation conventional nuclear options.

We have also seen that the PBMR cannot claim to be cost effective, and cannot remain within budget or delivery time (see section 8 below, appendix 1). By late 2009, the company could find no new foreign or private investors in the project. It is also unclear that there will be guaranteed customers. Eskom hedged its bets by agreeing to order PBMRs conditional upon them being the cheapest option, which they are unlikely to be. Without investment or customers, the maintenance of the project would have been a high price to pay given the need for maximum energy efficiency and given the impending astronomical rises in the price of electricity.

Satisfying the narrow technological nationalism of a few scientists and politicians is not the way to meet South Africa's energy planning needs. Should our human capital be diverted from this unviable project into more socially useful technological progress, we would all be the beneficiaries.

The government has made it clear that it is not going to salvage the PBMR project with taxpayers' money. However, it has left it with small grants and, together with support from private investment (mainly from Westinghouse), this may be a lifeline that could be the first step towards its resuscitation.

With South Africa having to face financial, energy and climate crises, it is time to re-evaluate our energy and technology priorities. It is time to shelve the PBMR openly and honestly, to end the days of special pleading by a small technocratic elite and to take responsibility for embracing carbon-free sources of electricity more vigorously.

POLICY RECOMMENDATIONS

1 Policy formulation

1.1 Currently policy formulation on energy is diffused across a number of governmental departments and parastatals. Since 2009 there has been a presidentially-appointed inter-ministerial committee on energy chaired by the public enterprises minister. This committee needs to have a website for listing its participants and publicising its discussions. The committee should also lay out a clear division of its own and departmental mandates.

1.2 Scrutiny over the work of the inter-ministerial committee should be undertaken by the appropriate parliamentary portfolio committee.

1.3 The interests of Eskom are not necessarily the interests of a national energy policy. This should be reflected in all policy deliberations. Eskom

should be one of a number of stakeholders in policy formulation.

1.4 Government has announced it will decide on nuclear policy in August 2010, but some ministers have already made pronouncements on policy matters. The process should be open and flexible. Decisions should be open to public participation. Ministers should not pre-empt the outcomes.

2. Finance

2.1 Government should make no further grants of taxpayer money to the PBMR company or any of its successor companies. The much-reduced subsidies to allow for the maintenance of a skeleton organisation should be ended.

2.2 All past, current and future grants, loans and investments to the PBMR company should be publicised.

2.3 Loans from financial institutions such as the World Bank should not be contracted for unsustainable energy solutions, such as coal and/or nuclear.

3. Regulation

3.1 The NNR should become a body independent of special interests. Its mandate should not flow from the Department of Energy, which promotes the use of nuclear energy, but from a more neutral body, such as the Department of Environmental Affairs. Alternatively the regulator should become autonomous, as a chapter nine institution recognised by the Constitution.

3.2 The NNR should not be folded into the NER. It should retain its specific brief and the specialised human capital should be able to undertake its mandate.

3.3 The NNR should be scrupulous in building a neutral reputation and should avoid employing former employees from the industry in its upper management and decision-making positions.

3.4 According to section 15.1 of the NNR Act, the CEO of the NNR should be appointed by the minister in consultation with board members and not over their heads.

3.5 NNR board members representing labour and affected communities should be granted a budget in order to communicate with their constituencies. There should be regular report-backs from these board members to their constituencies. The board should allow these representatives to raise legitimate public concerns, freely request information and promote transparency in the organisation.

3.6 The NNR website should contain more information, especially on releases of radioactivity, incidents and accidents related to mining and all other parts of the nuclear fuel chain. All past annual reports (including those of the Council for Nuclear Safety, the NNR's predecessor) should be available on its websites, and not just the most recent ones.

3.7 The NNR should hold regular consultations with its civil society stakeholders and make it easy for them to receive requested information and documentation.

4. Governance and environmental impact assessment

4.1 The so-called co-operative agreement between the NNR and the former DEAT on the conduct of the EIA should be reviewed. This allows for an EIA to occur without the final design of the PBMR being made public.

4.2 The EIA for the 165MWe design of the PBMR demonstration plant should be halted since this design will never be realised.

4.3 All EIAs on nuclear facilities should consider the full implications of the project, including the sourcing of materials, transport issues, design safety, disposal of nuclear waste and decommissioning of the project at the end of its life.

4.4 Government should make it clear that an EIA is site-specific and that the EIA for the demonstration reactor is not a substitute for future site-specific EIAs should the project ever be commercialised.

4.5 All objections to the EIA reports should be documented and fully addressed.

4.6 Given the controversial nature of the project, and the extensive public interest, the EIA should include as part of its penultimate phase a chance for an independent review panel to hold hearings and to put forward recommendations to the relevant department. While no provision is made in law for such an intervention, there is precedent from the case of the St Lucia EIA on granting titanium mining licences in what later became a world heritage site.

4.7 Records of decision should not occur prior to consideration of all objections.

4.8 In the case of EIAs related to nuclear facilities, the public should have ample time for comment. The fast-track response periods should be waived in favour of more extensive time to mobilise submissions.

4.9 An independent assessment should be made on whether the revised EIA regulations have

proved more effective in terms of environmental governance.

5. Public disclosure and transparency

5.1 The Department of Energy should release into the public domain past feasibility reports on the PBMR, including those issued by (i) the International Review Panel and (ii) PriceWaterhouse Cooper.
5.2 Minutes of Eskom board meetings reflecting the debates on the viability of the PBMR should be released into the public domain.
5.3 All state-held documents on the appointment and resignation of NNR CEO Maurice Magugumela should be released into the public domain.
5.4 The NNR should release all relevant documentation to the public without it having to resort to PAIA applications.
5.5 The NNR should develop a clearly-defined stakeholder consultation policy that allows for maximum interface between itself and the public.
5.6 The NNR in conjunction with other government agencies should develop effective co-operative governance initiatives for solutions to problems of radioactive contamination of soil and water in existing and former mining areas.

6. Training

6.1 The NNR should establish a training arm, based on revenue from each nuclear installation (at least one per cent of the sale of its licencing and other services).
6.2 Training budgets should be devoted to: (i) strengthening the human capital within the regulator; (ii) training on the impacts of nuclear installations and contaminated sites for the affected public within a reasonable distance of the facilities or sites; (iii) training for all affected municipalities through which nuclear material will be transported or in which there is evidence of past or potential radioactive contamination; and (iv) empowering parliamentarians in relevant committees (energy, environment, water, public enterprises, public accounts, science and technology, etc.) to provide effective oversight.

7. Deployment of human capital

7.1 Government should evaluate the skills of the 75 per cent of PBMR employees who are due to be retrenched.
7.2 As part of government's commitment to 'green' jobs, the employees should be reorganised into making a technical contribution to renewable energy projects, climate change mitigation, ecological rehabilitation and the strengthening of the regulatory apparatus. Otherwise the country runs the risk of losing their skills to the nuclear industry in other countries.

8. National energy debate

8.1 South Africa needs a national energy debate that will freely look at all the possibilities for energy production that the 21st century has opened up. In order to avoid this being a partisan affair, dominated by government and corporates, steps should be taken to ensure that the labour movement and organisations of civil society are centrally involved.
8.2 This debate should consider South Africa's energy future in terms of generation and distribution. It should evaluate the role of Eskom and of governance of the energy sector. It should map out an energy system that is attuned to the country's development needs, both social and ecological, and that seeks fair prices and ways of financing the system sustainably.
8.3 The debate should be informed by the urgency of climate change and the need to reduce carbon and other greenhouse emissions drastically. Climate and energy policy should not occur in separate spaces.
8.4 The energy debate needs to be integrated into national industrial planning processes. Industrial policy should prioritise a move towards low-emission, energy-efficient and water-wise solutions.
8.5 Outcomes should be pro-poor and aimed at reducing the income gap between rich and poor. Urban and rural energy poverty needs to be understood and overcome.

APPENDIX 1

Table 1: Pushing out the envelope: Design changes and time and cost overruns of the Demonstration Power Plant (DPP) and the Fuel Fabrication Plant (FFP) of the PBMR

Year	Size/output of DPP	Commence DPP	Complete DPP	Date of commercialisation	Estimated cost of DPP + FFP	Source
1998	110MWe	1999	2003	2003	R847 million	1, 2
1999					R2 billion	3
2000						
2001	130MWe	2002	2005	2009	R4 billion	2
2002a	137MWe					2
2002					R11,5 billion	1
2003	165MWe					4
2004		2007	2010	2012	R10 billion (DPP only)	2
2005		2007	2010	2013	R14,9 billion	5
2006a		2007	2011	2014	R16 billion	6
2006b		early 2008				7
2007		2011				8
2008						
2009a	80MWe + 200MW heat	[2016]	2018	[2023]	R31 billion	9
2009b		[2018]	'round about 2020'	[c 2025]		10

Sources: *1. Noseweek 74, December 2005, 9; 2. Steve Thomas, The economic impact of the proposed demonstration plant for the PBMR design, London: Public Services International Research Unit, University of Greenwich, November 2004, 4, 11, 19, 21; 3.Melanie Gosling, Plans for SA's nuclear power project 'implausible', The Star, 15 August 2005; 4. David Fig, Uranium road, Johannesburg: Jacana, 2005, 102; 5. Business Report, 25 May and 22 November 2005; 6. PBMR Co. presentation to ANC MPs study group, 15 September 2006; 7. Danette Breitenbach, Creating energy for the future, Professional Management Review, 17, 7, 2006, 36; 8. Business Day, 3 May 2007; 9. Business Report, 3 August 2009; 10. PBMR Co. website, Project Status page, updated October 2009, www.pbmr.co.za/index.asp?Content=175 (accessed 29 November 2009).*

Notes:

(i) Cost estimates are merely for the construction of the DPP and FFP and do not include costs of fuel enrichment, plant operation, insurance, waste management, or decommissioning.

(ii) Dates in square brackets are calculated from the claim by PBMR Co. that construction of the DPP will take 24 months and commercialisation around five years.

(iii) Eskom's inability to press for a 45 per cent tariff rise in its application to the regulator has prompted it to announce that it will further delay certain projects, 'including… nuclear power'. Marcia Klein, Eskom shelves projects to reduce price increase, *The Times* (Johannesburg), 2 December 2009, 12.

APPENDIX 2

Table 1: Sub-contractors for the demonstration and fuel fabrication plants

Sub-contractor	Task	Value	Date
Mitsubishi Heavy Industries (Japan)	Design and development of helium-driven turbo generator system	R72 million (=$12 million)	November 2004
Uhde (division of Thyssenkrupp, Germany)	Build a pilot fuel fabrication plant at Pelindaba	R156 million (=$20 million)	April 2005
SGL Carbon (Germany)	Production of graphite for the demonstration reactor	R156 million (=$20 million)	November 2005
Mitsubishi Heavy Industries (Japan)	Core barrel assembly for reactor pressure vessel	R100 million	December 2005
Equipos Nucleares S.A. (Spain)	Design and delivery of components for the plant's main power system pressure boundary, including the pressure vessel	R312 million	January 2006

Sources: *Roy Cockayne, Nuclear company looks for R11.3bn, Business Report, 3 May 2005; Roy Cockayne, SGL Carbon wins contract for pebble bed reactor plant, Business Report, 22 November 2005; Roy Cockayne, PBMR contracts usher in a new phase, Business Report, 7 December 2005; Geraldine Bennett, PBMR Press Release, 24 January 2006; Steve Thomas, PBMR: hot or not?, Nuclear Engineering International, 1 April 2010.*

ABBREVIATIONS

AEB	Atomic Energy Board, South Africa (1949–1970)
AEC	Atomic Energy Corporation, South Africa (1970–1999)
ANC	African National Congress of South Africa (1912–)
AP-1000	Westinghouse/Toshiba new generation conventional reactor
ASGISA	Accelerated and Shared Growth Initiative for South Africa
AVR	Arbeitsgemeinschaft Versuchsreaktor, Germany
BEE	Black Economic Empowerment
BEVA	Fuel Element Manufacturing Facility, Pelindaba
BNFL	British Nuclear Fuels Ltd
BWR	Boiling Water Reactor
CEO	Chief Executive Officer
CNI	Co-ordinated Network Investments
CNS	Council for Nuclear Safety (1988–1999)
CSIR	Council for Scientific and Industrial Research
DEAT	Department of Environmental Affairs and Tourism, South Africa (1994–2009)
DG	Director-General, the head of a department in the South African public service
DME	Department of Minerals and Energy, South Africa (1994–2009)
DPP	Demonstration Power Plant
DWE	Department of Water and Environment, South Africa (2009–)
EIA	Environmental Impact Assessment
EMG	Environmental Monitoring Group
EPR	European Pressurised Water Reactor designed by Areva
FFP	Fuel Fabrication Plant
FZJ	Juelich Research Centre, Germany
GT-MHR	Gas Turbine Modular Helium Reactor, USA
HTR GmbH	Gesellschaft fuer Hochtemperaturreaktoren
HT-10	High Temperature Reactor, China
HTR	High Temperature Reactor
HTGR	High Temperature Gas-cooled Reactor
HTR-PM	High Temperature Reactor – Pebble Bed Module, China
IDC	Industrial Development Corporation, South Africa
IPAP2	Industrial Policy and Action Plan
IST	Integrated Systems Technology Holdings (Pty) Ltd
JSE	Johannesburg Securities Exchange
KFA	Nuclear Research Facility, Germany
IAEA	International Atomic Energy Agency, Vienna
MLIS	Molecular Laser Isotope Separation
MPBR	Modular Pebble Bed Reactor, USA
NECSA	Nuclear Energy Corporation of South Africa (1999–)
NEMA	National Environmental Management Act, Act 108 of 1997
NEPAD	New Partnership for Africa's Development
NERSA	National Energy Regulator of South Africa
NERSA	National Energy Regulator of South Africa
NIASA	Nuclear Industry Association of South Africa
NNR	National Nuclear Regulator, South Africa (1999–)
NPT	Treaty on the Non-Proliferation of Nuclear Weapons
NRC	Nuclear Regulatory Commission, USA
OPEC	Organization of the Petroleum Exporting Countries
PAIA	Promotion of Access to Information Act, Act 2 of 2000
PBMR	Pebble Bed Modular Reactor
PBMR Co.	Pebble Bed Modular Reactor (Pty) Ltd
PWR	Pressurised Water Reactor
R&D	Research and development
SADF	South African Defence Force (1961–1994)
SANDF	South African National Defence Force (1994–)
SAHA	South African History Archive (non-governmental)
SANDF	South African National Defence Force (1994–)
SASOL	Suid-Afrikaanse Steenkool- en Oliemaatskappy
SECC	Soweto Electricity Crisis Committee
SWAPO	South-West Africa People's Organisation (1960–), Namibia
THTR	Thorium High Temperature Reactor, Germany
TRC	Truth and Reconciliation Commission, South Africa
UNITA	União Nacional pela Independência Total de Angola (National Union for the Total Independence of Angola)
UCOR	Uranium Enrichment Corporation
VHTR	Very High Temperature Reactor, USA

NOTES

1 Melanie Gosling, Pebble Bed Modular Reactor company to retrench 75% of staff, *Cape Times*, 19 February 2010.

2 Siseko Njobeni, State cuts off PBMR as it fails to find investor, customers, *Business Day*, 19 February 2010.

3 Siseko Njobeni, SA nuclear plan falters as PBMR chief quits, *Business Day*, 9 March 2010.

4 Chris Barron, More nuclear power 'a no-brainer' for future, *Sunday Times*, 14 February 2010.

5 Reuters, US firm moots PBMR injection, *Business Report*, 18 March 2010. Westinghouse is hoping to sell its AP-1000 reactor, a much larger pressurised water reactor, to South Africa, in competition with Areva's EPR.

6 Njobeni, SA nuclear plan falters, 2010.

7 Richard Rhodes, *The making of the atomic bomb*, New York: Simon and Schuster, 1986.

8 Gar Alperovitz, *The decision to use the atomic bomb*, New York: Vintage, 1996.

9 R A Cooper, Mineral constituents of Rand concentrates, *Journal of the Chemical, Metallurgical and Mining Society of South Africa* 24, 1923, 90–96, reprinted in *Journal of the South African Institute of Mining and Metallurgy* 94(3), 1994, 47–51.

10 L Taverner, An historical review of the events and developments culminating in the construction of plants for the recovery of uranium from gold ore residues, *Journal of the South African Institute of Mining and Metallurgy* 57(4), 1956, 5.

11 David Fig, Sanctions and the nuclear industry, in Neta C Crawford and Audie Klotz (eds), *How sanctions work: Lessons from South Africa*, Basingstoke: Macmillan, 1999, 78.

12 J Adams, *The unnatural alliance: Israel and South Africa*, London: Quartet, 1984; Zdenek Červenka and Barbara Rogers, *The nuclear axis: Secret collaboration between West Germany and South Africa*, London: Julian Friedmann, 1978.

13 A R Newby-Fraser, *Chain reaction: Twenty years of nuclear research and development in South Africa*, Pretoria: Atomic Energy Board, 1979, 98.

14 *Hansard,* 26 March 1986, gave the relative prices as 5,2 cents per kilowatt-hour for nuclear, compared with 1,89 cents per kilowatt-hour for coal. Eskom claimed (in S Murray, *Koeberg: Eskom's nuclear success story*, Cape Town: Churchill Murray, 1995, 111) that the two had become 'very competitive in terms of rands per kilowatt-hour sent out', without giving further substantiation.

15 Environmental Monitoring Group (EMG) and African National Congress (ANC) Western Cape Science and Technology Desk, *The nuclear debate: Proceedings of a conference on nuclear policy for a democratic South Africa*, Cape Town, 11–13 February 1994, Cape Town: EMG, 1994, 5.

16 Mauritius claims sovereignty over the Chagos Islands but on achieving independence in 1965, Britain declined to hand them over. After dumping the destitute inhabitants of Diego Garcia on Mauritius and the Seychelles, Britain rented the atoll to the US military in 1971. Like Guantánamo, the US base on Diego Garcia has been linked to 'extraordinary rendition' (imprisonment outside the law) of prisoners of war. See Jamie Doward, British island used by US for rendition, *The Observer*, 2 March 2008.

17 South Africa, Department of Minerals and Energy (DME), *White paper on the energy policy of the Republic of South Africa*, Pretoria: DME, 1998, section 7.2.iv.

18 DME, *White paper on the energy policy of the Republic of South Africa*, 1998, sections 7.2.iii, v.

19 Numerous examples of the industry's special pleading exist. These include the notions that South Africa's industrial path requires nuclear energy, that renewable energy cannot service the country's base energy load and that an end to state subsidies would undo the industry's required research and development efforts. These arguments were reflected in many ministerial statements, particularly those of ministers Erwin, Mlambo-Ngcuka, Sonjica, Xingwana, and Hogan. An example of the impact of the lobby on government took place in April 2005. Watchdog organisation Earthlife Africa had informed the media of the existence of an unfenced radioactive calibration centre in a dairy farming area close to NECSA headquarters at Pelindaba. Earthlife was subsequently attacked for doing this by the then minerals and energy minister, Phumzile Mlambo-Ngcuka, who threatened to pass legislation outlawing scaremongering and signalling government's intention to place more stringent controls over the public pronouncements of NGOs. President Mbeki endorsed the minister's response. Within a few days the NNR confirmed that indeed radioactivity was emanating from the site and ordered NECSA to take appropriate precautions to impede public access, thus vindicating Earthlife's position. It is unlikely that the minister and president would have responded on this matter without considerable pressure from the industry.

20 See the arguments laid out at the end of the first section.

21 Nuclear Industry Association of South Africa, press release, 25 March 2010.

22 Such as the Magnox reactor in the UK.

23 The Canadian CANDU reactor was installed locally and the technology passed on to India.

24 The Chernobyl reactors were a type called RBMK, produced in the Soviet Union. In late April 1986, a test of one of the reactors went out of control and an immense amount of radioactivity entered the atmosphere. Many emergency workers died of exposure while trying to place a concrete sarcophagus over the reactor. Many thousands of children have subsequently been subjected to or born with cancers, disfigurement and other disabilities. An area of 30 km around the reactor had to be evacuated. Agricultural lands have been contaminated.

25 With the exception of a loan of $40 million granted to Italy in 1959. See World Bank Archives, Pages from World Bank history: Loan for nuclear power, 22 August 2003, available at http://web.worldbank.org/WBSITE/EXTERNAL/EXTABOUTUS/EXTARCHIVES/0,,contentMDK:20125474~pagePK:36726~piPK:36092~theSitePK:29506,00.html (accessed 20 November 2009). However, Friends of the Earth in the Czech republic have accused the World Bank of defying its own policy of no nuclear loans by granting $246 million in 1994 to CEZ, the Czech utility, some of which went towards financing the disastrous Temelin reactors (see Nuclear Information Research Service, The World Bank: A nuclear power lender, at http://www.nirs.org/mononline/worldbank-summarycabg.htm (accessed 7 April 2010) and World Nuclear

Association, Nuclear power in the Czech Republic, updated March 2010, at http://www.world-nuclear.org/info/inf90.html (accessed 7 April 2010)

26 This position is under pressure as countries like South Africa, keen to expand their nuclear programmes, are lobbying to reverse it.

27 Modular means that a number of units can be joined together depending on need.

28 Rainer Moormann, Pebble bed reactor safety revisited, *Nuclear Engineering International*, 1 April 2009, http://www.neimagazine.com/story.asp?storyCode=2052589 (accessed 30 September 2009).

29 Anonymous reactor operator, Fort St Vrain Power Station History, 2008, available at http://www.fsvfolks.org/FSVHistory_2.html (accessed 30 September 2009).

30 Licence awarded for high-temperature reactor technology: Contract between HTR GmbH and Eskom, Energy Report, 1 May 1999, available at http://www.allbusiness.com/company-activities-management/company-strategy/7407521-1.html (accessed 30 September 2009).

31 Moormann, Pebble bed reactor safety revisited, 2009. Moormann's article elicited a rejoinder by a senior consultant on nuclear safety to the PBMR company. See Albert Koster, Pebble bed reactor safety in perspective, *Nuclear Engineering International*, 1 June 2009, reproduced at http://www.pbmr.com/index.asp?Content=217&Article=107&Year=2009 (accessed 30 September 2009). The article dealt summarily with only three of the items on Moormann's checklist in Box 1, which are those asterisked in the box.

32 Andrew C Kadak, A future for nuclear energy: Pebble bed reactors, *International Journal of Critical Infrastructures*, 1, 4, 2005, 330–45, Table 1, 336.

33 General Atomics, Gas Turbine Modular Helium Reactor, available at http://gt-mhr.ga.com/ (accessed 30 September 2009).

34 US Department of Energy, (Idaho National Laboratory), Very-High-Temperature Reactor (VHTR), available at https://inlportal.inl.gov/portal/server.pt?open=514&objID=2251&parentname=CommunityPage&parentid=13&mode=2&in_hi_userid=291&cached=true (accessed 30 September 2009).

35 Adams Atomic Engines Inc., available at http://www.atomicengines.com (accessed 30 September 2009). There is a strong link with the Romawa project (see two notes below).

36 Jana Miller, Powering up a growing nation, *Nuclear Power International* 1, 2, 21–23.

37 Romawa, *The Nereus Project*, available at http://www.romawa.nl/nereus/overview.html (accessed 30 September 2009)

38 Pebble Bed Modular Reactor (Pty) Ltd, available at http://www.pbmr.co.za (accessed 30 September 2009)

39 Japan Atomic Energy Authority, HTTR, available at http://httr.jaea.go.jp/eng/index_main_eng.html (accessed 30 September 2009).

40 Keith Campbell, SA, China PBMR projects to cooperate, *Engineering News*, 30 March 2009, available at http://www.engineeringnews.co.za/article/south-africa-china-pbmr-projects-to-cooperate-2009-03-30 (accessed 30 September 2009); Keith Campbell, SA, China unveil PBMR cooperation agreement, *Engineering News*, 10 April 2009, available at http://www.engineeringnews.co.za/article/south-africa-china-pbmr-projects-to-cooperate-2009-04-10 (accessed 30 September 2009).

41 Wyndham Hartley, Hogan positive about pebble bed modular reactor in South Africa, *Business Day*, 17 September 2009.

42 Quote displayed prominently on the home page of PBMR (Pty) Ltd. at http://www.pbmr.co.za/ (accessed 30 September 2009).

43 *Engineering News*, 20 September 1991; Jacklyn Cock, The link between security and development: The problem of light weapons proliferation in Southern Africa, *African Security Review* 5, 5, 1996.

44 These included senior weapons developer Prof Andre Buys.

45 Peter de Ionno, Nuclear scientists threaten to tell all, *Sunday Times* (Johannesburg), 27 March 1994.

46 Makhudu Sefara, Weapons of mass destruction linked to South African men, *News24 wire service*, Johannesburg, 27 February 2005, quoted in KwaZulu-Natal Law Society, Earth, wind and fire, 28 February 2005.

47 BEVA stands for *brandstofelementvervaardigingsaanlegging*, which is Afrikaans for fuel element fabrication facility. Recently the facility has been revived for the manufacture of the pebbles for the PBMR.

48 See EMG et al, *The nuclear debate*, 1994.

49 Abdul Minty, in EMG et al, *The nuclear debate*, 1994, 15, stated: 'There is perhaps no other project on which so much money and resources have been wasted during the apartheid years.' Indeed, for many years afterwards, there were curious unspecified budget lines in the DME budgets that were said to have reflected continued repayments of the loans made for the bomb programme.

50 David Fig, Does South Africa's nuclear industry deserve to survive? in EMG et al, *The nuclear debate*, 1994, 19–24.

51 Recommendations to the ANC Science and Technology Policy Division arising from ANC and alliance delegates, in EMG et al, *The nuclear debate*, 1994, 234, recommendation 3.4.

52 Waldo Stumpf, The creation of national wealth through technology: The AEC's 2000+ plan. in EMG et al, *The nuclear debate*, 1994, 25–37.

53 Michael Kantey, That was then and this is now: Shifting ANC policy on nuclear energy, unpublished paper prepared for the Institute for Security Studies, January 2009, quoting http://www.pbmr.com/contenthtml/files/File/Chronoloy.pdf.

54 From the 1980s Eskom had slowly been transformed into a commercial company and was no longer a non-profit government utility. It was accountable to the DPE and not the DME. It had access to bond finance and made most of its own commercial decisions. See Leonard Gentle, Escom to Eskom: From racial Keynesian capitalism to neo-liberalism, 50–72, in David A Macdonald (ed.), *Electric capitalism: Recolonising Africa on the power grid*, London: Earthscan, 2009.

55 Kantey, That was then and this is now, 2009.

56 Until it severed its connection with the PBMR company in 2002, Exelon was helping to steer the licencing of the PBMR through the US Nuclear Regulatory Commission. See entry for PBMR in US NRC, Fact sheet on next generation reactors, available at http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/next-gen-reactors.html (accessed 31 March 2010).

57 David Fig, *Uranium road: Questioning South Africa's nuclear direction*, Johannesburg: Jacana, 2005, 98. Note: Eskom previously owned 100 per cent of the company, but decided to diversify. Its plan was to retain 30 per cent and grant 10 per cent to a black economic empowerment company, but this never occurred.

58 PBMR (Pty) Ltd, *PBMR: Powering the future*, Pretoria: PBMR (Pty) Ltd, c. 2006, 3.

59 DME, *White Paper on Energy Policy of the Republic of South Africa*, 1998, 53, 60, 63. It should also be noted that the far less inclusive Energy Summit of 2007 noted the potential expansion of the nuclear industry but in a context in which the regulatory and safety infrastructure was inadequate. See DME, Outcomes of the energy summit hosted from 25 to 27 September 2007, Pretoria: DME, 2007, 72–4.

60 David Kraft, Exelon pulls out of pebble bed project, *Nuclear Monitor*, 3 May 2002, 1.

61 PBMR (Pty) Ltd, *PBMR: Powering the future*, 2006.

62 Tom Ferreira, Exelon withdraws from PBMR project, PBMR News release, 16 April 2002.

63 Melanie Gosling, Plans for SA's nuclear power project 'implausible', *The Star* (Johannesburg), 15 August 2005.

64 Steve Thomas, Pebble bed: Hot or not? *Nuclear Engineering International*, 1 April 2009. Drawn from www.neimagazine.com/story.asp?storyCode=2052590 (accessed 29 November 2009).

65 Fig, *Uranium road*, 2005, 100.

66 US Nuclear Regulatory Commission, Advisory Committee on Reactor Safeguards, Trip report: Travel by D.A. Powers to attend the high-temperature gas-cooled reactor safety and research issues workshop, Rockville, MD, 10–12 October 2001, Rockville MD: USNRC, 4–5.

67 Toshiba, Toshiba acquires Westinghouse from BNFL, press release at www.toshiba.co.jp/about/press/2006_02/pr0601.htm (accessed 30 November 2009); Kazatomprom buys 10% stake in Westinghouse, *World Nuclear News*, 22 October 2007, 1.

68 Westinghouse boost for SA's pebble bed reactor, *Business Day*, 24 July 2007.

69 Roy Cockayne, PBMR part of team awarded $3m US engineering contract, *Business Report*, 3 October 2006.

70 Terence Creamer, Westinghouse wins $30m Koeberg fuel contract, *Engineering News*, 30 November 2009.

71 US-based Westinghouse was a reactor design and building company that developed the early blueprint for the pressurised water reactor design on which Koeberg, built by Framatome, was based. After Chernobyl, Westinghouse passed into British ownership as part of BNFL. BNFL was one of the investors in the PBMR company. When BNFL folded, its Westinghouse section was sold on to Toshiba. Westinghouse has therefore a strong interest in the PBMR. It has developed the AP-1000 reactor which competed with Areva's EPR in the aborted tender for Nuclear-1, South Africa's next PWR. Both Westinghouse and Areva have offices in South Africa and strong connections to the local nuclear industry.

72 These discussions were used by the government to cancel the planned nuclear summit set to be held in parliament in mid-April 2004. This was a long-negotiated attempt by civil society organisations to debate with parliamentarians and others the future of the nuclear industry. The state feared that Areva would gain the impression that the anti-nuclear forces in South Africa were substantial. It cancelled the summit, citing the proximity of the elections as an excuse.

73 Roy Cockayne, Nuclear company looks for R11.3bn, *Business Report*, 3 May 2005; Roy Cockayne and Andile Ntingi, More time needed for pebble bed deal, *Business Report*, 25 May 2005; Lynda Loxton, PBMR Company is not 'struggling' to get investors, *Business Report*, 26 May 2005.

74 Calculated from investors' page of PBMR website, available at http://www.pbmr.com/index.asp?Content=176 (accessed 1 December 2009); and PBMR nuclear demo plant rockets to R31 bn, *African Energy News Review*, 6 August 2009, available at http://www.energynews.co.za/web_main/article.php?story=20090806121129783 (accessed 1 December 2009).

75 Eskom had signed a virtually unenforceable Memorandum of Understanding with the PBMR company to the effect that it would purchase around 10 units if the price was competitive. Most of the PBMR's production was expected to be exported.

76 Jaco Kriek, Update on the PBMR Co.: Presentation to parliamentary portfolio committee on public enterprises, 13 August 2009, slide 9/20.

77 Through the Eskom Conversion Act, Act 13 of 2001.

78 Eskom, *Annual Report 2009*, Johannesburg: Eskom, 228.

79 For a full appraisal of these events, see David Fig, Darkness and light: Assessing the South African energy crisis, in William Freund and Harald Witt (eds), *Development dilemmas in South Africa*, Pietermaritzburg: University of KwaZulu Natal Press, 2010 (in press).

80 *Business Day*, 1 December 2009.

81 See, for example, the very articulate submission by Earthlife Africa Johannesburg to NERSA on this question, Earthlife MYPD2 Submission.pdf, 30 November 2009, copy in author's possession.

82 National Energy Regulator of South Africa (NERSA), *Decision in the matter regarding revenue application – Multi Year Price Determination 2010/11 to 2012/13 (MYPD 2) by Eskom Holdings Ltd.*, Pretoria: NERSA, 24 February 2010. In fact the increases will be 24,8% in 2010/2011, 25,8% in 2011/2012, and 25,9% in 2012/2013.

83 Carli Lourens, World Bank considers $3.75bn loan to fund Eskom's expansion, *Business Report*, 24 November 2009.

84 Lance Greyling, Independent Democrats whip and spokesperson for public enterprises, in an open letter to Dr Robert Zoellick, president of the World Bank, 9 March 2010, reproduced at http://www.politicsweb.co.za/politicsweb/view/politicsweb/en/page71619?oid=164766&sn=Marketingweb+detail (accessed 24 March 2010).

85 Steve Thomas, *The economic impact of the proposed demonstration plant for the PBMR design*, London: Public Services International Research Unit, University of Greenwich, 2004, 15.

86 Earthlife Africa Cape Town, ELA loses case for Eskom board minutes, press release, 15 December 2005, at http://www.earthlife-ct.org.za/PopUpDisplay.php?ObjectID={9CCE3872-1796-488D-9190-A5A16A4DC572} (accessed 2 December 2009).

87 A more comprehensive treatment of Earthlife's use of PAIA to obtain information from the nuclear industry is at David Fig,

In the dark: Seeking information about South Africa's nuclear energy programme, in Kate Allan (ed), *Paper wars: Access to information in South Afric*a, Johannesburg: Wits University Press, 2009, 56–85, 246–252.

88 What the government is hiding about the pebble bed project, *Noseweek* 74, December 2005, 8–11.

89 PBMR Co., *Report on the proposed demonstration model and potential commercialisation of the PBMR*, Centurion: PBMR Co., 2002; PBMR Co., *Final environmental impact report for the proposed PBMR demonstration plant at the Eskom nuclear power station site in the Western Cape, South Africa*, Centurion: PRMR Co., 2002. See also Fig, In the dark, 2009, 81.

90 Thomas, *The economic impact*, 38.

91 Ibid.

92 Thomas, *The economic impact*, 39.

93 Peter Wathern, *Environmental impact assessment: Theory and practice*, London: Routledge, 1990; Peter Morris and Riki Therivel (eds), Methods of environmental impact assessment, London: UCL Press, 1995.

94 Quentin Wray, New rules to speed up EIA applications, *Business Report*, 20 April 2006.

95 For example, the revised regulations allow for smaller developments to be subjected to less stringent assessment and for class applications for multiple activities under one process, which run the risk of avoiding dealing with the ecological specificities of the different localities.

96 Fig, *Uranium road*, 107.

97 Maya Aberman, Cabinet accepts court judgment, Earthlife Africa Cape Town press release, 8 February 2005, available at http://www.earthlife-ct.org.za/PopUpDisplay.asp?ObjectID={8FFCDF4A-48EC-4594-B76C-303-A966557CED} (accessed 3 December 2009).

98 Prof Steve Thomas, University of Greenwich, personal communication.

99 A small percentage of this would have been the investment undertaken by BNFL/Westinghouse/Toshiba.

100 Justin Brown, Cost of nuclear demo plant soars to R31bn, *Business Repor*t, 3 August 2009.

101 National Nuclear Regulator (NNR), *Annual Report 2007/8*, Centurion: NNR, 2008, 4, where the Chair of the Board, Prof May Hermanus, said that the 'most daunting challenge still facing the NNR is the ability to attract and retain skilled and experienced personnel to carry out its mandate'. In the NNR's *Annual Report 2008/9*, 9, the Acting CEO, Guy Clapperson, said: 'It will also be important to invest more resources in the NNR to ensure that the nuclear regulatory capacity of the country can respond effectively to the entire value chain of a larger nuclear energy sector.' Clapperson also bemoaned the inability of the NNR to retain technical staff required to sustain regulatory oversight functions.The NNR reported that in 2008–2009, its income was R85,8 million of which R20 million was in the form of government grants, and R65 million was recuperated from licencing and other services. The staff complement was 90. NNR, *Annual Report 2008/9*, Centurion: NNR, 62, 91.

102 Thanks to the initiative of Mariette Liefferink of the Federation for a Sustainable Environment, who was subsequently appointed to the Board of the NNR.

103 See note 19.

104 The National Nuclear Regulator Act, Act 47 of 1999, specifies in section 15(1): 'The Minister must, *after consultation with the board*, appoint a person with suitable qualifications as chief executive officer of the Regulator' (emphasis added). See the Act at http://www.info.gov.za/view/DownloadFileAction?id=70614 (accessed 24 March 2010).

105 'Revolving door' is a term for the movement of personnel between roles as regulators of particular industries, and roles within the industries affected by regulation. This creates an unhealthy relationship regulator and the regulated industry and can lead to regulatory capture whereby the regulator acts in the interests of a key stakeholder rather than in the public interest.

106 NNR, *Annual Report 2008/9*, Centurion: NNR 2009, 6–7.

107 NNR, *Annual Report 2008/9*, Centurion: NNR 2009, 5.

108 Interviews with members of Earthlife Africa and the Pelindaba Working Group, 13 February 2010.

109 See Kate Allen, *Paper wars: Access to information in South Africa*, Johannesburg: Witwatersrand University Press, 2009.

110 For a comprehensive annotated list of these requests see Fig, *In the dark*, 2009, 82.

111 Fig, *In the dark*, 2009, 83.

112 In addition to Eskom Holdings, these included Nedbank, Sun Air, Murray and Roberts, Glaxo-Smith Klein and Creda Communications.

113 These included IBM, Standard Bank, Vodacom, Norwich Life, Old Mutual, Nampak, IST Holdings and Sasol.

114 About Reuel Jethro Khosa, available at http://www.reuelkhoza.co.za (accessed 14 December 2009).

115 All in the pebble bed together, *Noseweek* 66, April 2005, 14.

116 Richard Lapper and Peggy Hollinger, Eskom cancels plans to build nuclear plant, *Financial Times*, 5 December 2008.

117 Terence Creamer, Eskom terminates Nuclear-1 procurement, *Engineering News*, 5 December 2008.

118 Quentin Wray, *New rules to speed up EIA applications*, 2006.

119 See especially section 10 of the Legal Resources Centre submission in the PBMR EIA Revised Scoping Report, available at http://www.pbmr-eia.co.za/documents/Revised%20Scoping%20Report%2002_02_07/Chapter%208%20App%208%20Documentation%20from%20LRC.pdf, dated 7 February 2002 (accessed 15 December 2009) and also LRC's submission regarding Draft EIA Report (for Earthlife Africa, Cape Town and Johannesburg), dated 28 October 2008, addressed to ACER Africa, copy in author's possession.

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ABOUT THIS PAPER

A surprise announcement was delivered to the pebble bed modular reactor (PMBR) project in South Africa's 2010 budget – it would no longer obtain significant state funds. As a result the project had to dismiss 75 per cent of its staff. It had spent in the region of nine billion rands of state funds without having realised any of its plans. Furthermore, it had been unable to attract significant outside investment or potential clients. Given the central importance of energy policy in South Africa, it is more important than ever that projects like the PBMR are evaluated for their necessity, viability, affordability, sustainability, and contribution to the country's development path. While the government appears to have dropped the PBMR for the present, recent media rhetoric suggests that it is still committed to adding substantial amounts of nuclear power to its future energy mix. This effort seems to being made without first addressing problems relating to democratic governance, public policy making and promoting the special interests of lobby groups. This paper seeks to raise such issues within an appraisal of the country's checkered nuclear history and its development aspirations.

ABOUT THE AUTHOR

Dr David Fig is an independent environment policy researcher. He was awarded a doctorate from the London School of Economics in 1992. He was an anti-apartheid exile in the UK from 1973–1983. Upon returning to South Africa he became deeply engaged in working to support the emerging South African labour movement. Since 1983 he has been involved in sustainable energy and anti-nuclear activism, monitoring nuclear power and uranium mining. He has published extensively on nuclear energy, including authoring *Uranium Road: Questioning South Africa's Nuclear Direction*, which was published in 2005 by Jacana and critiques the nuclear industry in South Africa. In 1997 he helped found Biowatch South Africa, which won a case on the right to information on GMO releases against the state and multinational company Monsanto. Since 1999 Fig has chaired the Biowatch board of trustees. He has also done extensive work in journalism, reviews and advocacy publications and made presentations at various local and international forums.

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