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24 October 2008

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Dear Sir/Madam

**SUBMISSION REGARDING DRAFT ENVIRONMENTAL IMPACT ASSESSMENT REPORT**
**DEAT REFERENCE : 12/12/20/745 PROJECT NO. J27196**
**ENVIRONMENTAL IMPACT ASSESSMENT FOR 400MW(t) PEBBLE BED MODULAR REACTOR DEMONSTRATION POWER PLANT**

We act for Earthlife Africa(Cape Town) and Earthlife Africa (Johannesburg)

Our clients have instructed us to make the following submissions in regard to the draft environmental impact assessment report dated September 2008 for the Pebble Bed Modular Reactor demonstration power plant.

Executive summary

A Safety issues

B Waste issues

C Economic issues

## A SAFETY ISSUES

***The Environmental Impact Assessment Report ("EIAR") fails to place before the decision maker relevant considerations which would enable a lawful decision.***

### *1.1 Legal context*

The Promotion of Administrative Justice Act (PAJA) No 3 of 2000 section 6(2)(e)(iii) requires administrative decisions to take into account all relevant considerations in order to be lawful. This matter concerns an application for an authorization for a number of activities identified in terms of Section 21(1) of the Environment Conservation Act, 73 of 1989. The following legislative provisions set out relevant provisions which must be taken into account in decision making in regard to such authorization.

1.1.1 National Environmental Management Act 107 of 1998, section 2(4)(a) and in particular section 2(4)(a)(vii) & (viii)[1], section 2(4)(i)[2]. Minimum requirements for environmental impact assessment procedures are set out in:

*Section 24(4)(b) Investigation of the potential impact of the activity and its alternatives on the environment and the assessment of the significance of that potential impact;*
*Section 24(4)(c): Investigation of mitigation measures to keep adverse impacts to a minimum, as well as the option of not implementing the activity;*
*Section 24(4)(c): Reporting on all gaps in knowledge, the adequacy of predictive methods and underlying assumptions, and uncertainties encountered in compiling the required information.*

1.1.2 Regulations regarding activities identified under section 21(1) of the Environment Conservation Act, 73 of 1989[3]. These regulations provide:
"*Regulation 7: Plan of study for environmental impact assessment.*

*In terms of this regulation the applicant must submit a plan of study for the environmental impact assessment which must include:*
*(a) a description of the environmental issues identified during scoping that may require further investigation and assessment.*

*Regulation 8: Submission of environmental impact report.*

*After the plan of study for the environmental impact report has been accepted, the applicant must submit an environmental impact report to the relevant authority which must contain -*
*(a) a description of each alternative, including particulars on*
*(i) the extent and significance of each identified environmental impact; and*
*(ii) the possibility for mitigation of each identified impact."*

### *1.2 Relevant considerations for study set out in the Plan of Study*

The EIAR is required to assess all potential impacts of the PBMR DPP and by implication potential impacts under normal, abnormal or upset conditions. This requirement is set out in paragraph 4.1.6 of the Plan of Study for the EIAR and includes:

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[1]2(4)(a) Sustainable development requires the consideration of all relevant factors including the following:
(vii) that a risk aversion and cautious approach is applied which takes into account the limits of current knowledge about the consequences of decisions and actions; and
(viii) that negative impacts on the environment and on people's environmental rights be anticipated and prevented and where they cannot be prevented, are minimized and remedied.
[2] The social, economic and environmental impacts including disadvantages and benefits must be considered, assessed and evaluated and decisions must be appropriate in the light of such consideration and assessment.
[3] GNR1183 in GG18261 of 5 September 1997

*"The impacts of radiation emissions from the PBMR DPP on the plant itself and on its surrounding environment and the impact of various incident scenarios with specific reference to excessive heating of the fuel, carbon fires, aircraft collisions and loss of coolant."*

These requirements are amplified in the DEAT letter of 25/8/2008 and the Plan of Study states that states that the DEAT would make the final decision relating to all radiological matters relating to the EIAR.[4]

The Plan of Study states that the following specialist studies will be provided in order to answer the following questions.

(a) Air quality:
*"What is the anticipated impact on the health of persons living in the area of influence of the proposed PBMR DPP due to emissions (radioactive and non radioactive) from the said proposed activity"*[5]

(b) Radiological health and safety
*"What is the anticipated impact on the health of persons living in the area of influence of the proposed PBMR DPP due to radioactive pollution from the facility during normal operating conditions as well as during an incident"*[6]

The letter from the Department of Environmental Affairs & Tourism to the consultants about the revised plan of study for the environmental impact assessment dated 25/8/2008, (the DEAT letter of 25/8/2008) required the study to:

"*articulate clearly and simply the findings of the EIAR in answer to a number of integrating questions which would inform the DEAT's decision making. Examples of questions (based on issues raised repeatedly during the EIAR process to date) that would need explicit answers in the consideration of alternatives and the assessment and evaluation of impacts of the proposed PBMR DPP include*

- *What are the potentially significant environmental risks associated with the PBMR DPP (not only risks of the project but risks to its effective implementation)?*
- *What if any would be the scale of (a) impacts, (b) risks and (c) irreplaceable losses under normal or upset conditions*
- *What would be the principal mitigation, management, monitoring and emergency measures proposed"*

## 1.3 *Relevant issues relating to radiological safety raised by Earthlife Africa in scoping.*

In regard to the first EIAR for the PBMR DPP (" the first EIAR ") a number of submissions regarding safety were made by LRC on behalf of Earthlife Africa in 2002[7] (Annexure "A" hereto). These issues were not adequately addressed in that EIAR and were raised again, and included in the scoping process for the current EIAR.[8] The issues are required to be considered in the EIAR . They are included herein for completeness:

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[4] Plan of study parag 2.7.5

[5] Plan of study paragraph 6.4.1

[6] 6.4.19

[7] *Submissions on the Pebble Bed Modular Reactor and Associated Fuel Manufacture Draft Environmental Impact Reports: Analysis of Legal Compliance* submitted by the Legal Resources Centre on behalf of Earthlife Africa, September 2002 ("LRC submission 2002") Most of these issues had been raised for discussion at a workshop in October 2001 by Dr Dana Powers of the NRC Advisory Committee on Reactor Safeguards which was also attended by G A Clapisson of the NNR. These issues remain under discussion in conferences around the world. See footnote 24 and parag 1.5(c) below.

1.3.1 Safety concerns mentioned in the first EIAR:

- Failure to make the Safety Analysis Report ("SAR") available for critical public scrutiny;[9]
- Failure to address
    - the lack of adequate shutdown systems; the consideration of an accidental fire;[10]
    - the understatement of the temperatures that the PBMR core could attain, the rate of release of radio isotopes release from fuels spheres and the risk of ignition of the core as a result of sudden ingress of air.[11]
- The understatement of risks of the PBMR and features that make it "inherently unsafe"[12] in that the following issues were not discussed:
    - the PBMR design lacks active controls for modulating radioactive releases from a disrupted core;
    - nuclear fission in the PBMR core is inherently chaotic and unstable;
    - the structural integrity of graphite is vulnerable to conditions that occur within the PBMR core;
- Failure of the first EIAR came to recognize that secondary containment is required by defence in depth principles.[13]

1.4 ***Failure to set out assumptions***

Section 24(4)(e) of the National Environmental Management Act requires procedures for the investigation and assessment and communication of the potential impacts of activities to report on *gaps in knowledge, the adequacy of predictive methods and underlying assumptions and uncertainties* encountered in compiling the required information.

In addition, there is a general requirement under PAJA[14] to place all relevant information before the decision maker and this would include information about *gaps in knowledge, the adequacy of predictive methods and underlying assumptions and uncertainties encountered in compiling the required information,* given the hazardous nature of the proposed nuclear installation. It is submitted that the report fails to comply with this requirement.

***The report fails to indicate that all conclusions regarding radioactive emissions and theirimpacts in the EIAR are based on a design concept and not a final design, and that the safety case has not been finalised;***

Previous documentation relating to the EIAR makes it clear that the PBMR DPP at this stage is based on a design concept rather than a final design, and as such is not yet complete.
The submission by Earthlife African to the Draft Scoping Report Earthlife Africa included an expert report of Gordon Thomson entitled *"Safety of the Proposed South African Pebble Bed Modular Reactor: Technical Issues, Status of Knowledge and their Documentation" (the*

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[8] *Legal Compliance Analysis of the Revised Final Environmental Scoping Report for a Proposed 400 MW PBMR DPP* submitted by The Legal Resources Centre on behalf of Earthlife Africa 9 March 2007 paragraph 8.2(b)
[9] LRC submission 2002 paragraphs 5.1.2 and 5.1.3
[10] id para 5.1.3.2 and 5.1.3.3
[11] id parag 5.1.4.2, 5.1.4.3 and 5.1.4.4
[12] id para 5.1.4
[13] id parag 5.1.5
[14] section 6(2)(e)(ii)

*"Thompson Report",* Annexure "B" hereto). This report states that claims as the safety of the PBMR DPP are based on a design concept rather than a final design:

*"The design of the proposed PBMR has passed through at least two substantial changes since 2001, as discussed in section 2.2 of this report. These changes, and the absence of a prototype reactor indicate that the proposed PBMR should be considered as a design concept rather than a design that is ready to be built. Design changes of the magnitude that have occurred for this PBMR can substantially affect the safety of the reactor. Thus no significant conclusions can be drawn regarding the safety of the proposed PBMR until two conditions have been satisfied. First, the design must have been finalised. Second, the design must have been subjected to a safety assessment performed according to Best International Practice. "*[15]

Subsequent hereto recent media reports have confirmed this position and in particular that the safety case is still being considered and is not finalized yet, and this includes the consideration of whether secondary containment is to be required.[16]

The EIAR report is required to evaluate all actual and *potential* impacts of the activity,[17] operating under abnormal and normal conditions. It is submitted that the EIAR cannot evaluate the potential impacts of a nuclear reactor which is not based on a design that is ready to be built. The EIAR is required to pertinently drawn to the attention of the decision maker these assumptions in order to comply with NEMA. It is submitted that the EIAR does not do so and is therefore noncompliant with section 24(4)(e) of NEMA.

### *1.5 Failure to set out gaps in knowledge*

#### *1.5.1 Failure to report of gaps in knowledge: the report fails to disclose the degree of uncertainty surrounding safety issues of the PBMR.*

The EIAR gives the impression that key issues in relation to design and safety have been finalized. The report fails to refer to uncertainties regarding safety that are currently being studied by Eskom This renders the EIAR is incomplete and confusing and does not comply with NEMA s 24(4)(e). For example parag 3.14 states:

> *"a key design aspect of the PBMR DPP is that it is intended to be safer than other commercial nuclear power technologies. It is said to be inherently safe because should a worse case accident scenario occur, no human intervention would be required in the short or medium term to ensure that the reactor shuts down safely. The factors which result in the inherent safety of the technology are design, materials used, fuel characteristics, the physics involved and the geometrical arrangement of the reactor unit components."*

The EIAR also states[18] that nuclear accidents mentioned in section 3.11.2[19] are not considered to be possible because of the following attributes of the PBMR technology:

- "*Peak temperature that can be reached in the core if the reactor : 1600 C is well below the temperature that may cause damage to fuel;*
- *Analysis have shown that reactor core meltdown for PBMR DPP is not credible;*

[15] Thompson report parag 1
[16] Steve Lennon, Eskom, report in the Cape Times 20 September 2008
[17] NEMA section 24(4)
[18] parag 3.14
[19] this paragraph is however not included in the EIAR, and appears to be a mistake, as is footnote 21 of the EIAR

- *The reactor is housed in a building part of which is strengthened enclosure around the main power system and is designed to withstand significant external forces such as aircraft impacts, seismic events , tornadoes or explosions caused by saboteurs;*
- *The walls surrounding the reactor pressure vessel are 2.2 metres thick reinforced concrete*."

The EIAR specialist study on radiological safety and health states:

*"For all Beyond Design Base Accidents the public doses demonstrate compliance with the Design Base Accidents regulatory dose limit. The potential radiological impact during Accident Conditions is thus considered to be of low significance and localised, with the highest impact close to the facility and the impact lessens further from the facility".*[20]

### *a) Eskom does not know how much radioactive dust will enter the primary circuit.*

The EIAR states that the PBMR design is based on the HTR-modul design which in turn is based on experience gained from the AVR and THTR reactors. The AVR is described in the EIAR report as follows:

*"during its 22 years of operation, the design proved the superior behaviour of the coated particle fuel concept, the favourable safety characteristics of the core, and even fulfilled the safety requirements listed today for modern reactors in terms of control of improbableevents"*[21]

However the PBMR Pty Ltd has indicated that it has concerns about the amount and fate of radioactive dust which accumulated in the AVR reactor that would contribute to the source term in equations predicting releases of radioactivity from the PBMR. A report from R Moormann of the Julich Nuclear Research Institute[22]("JFZ") which designed the AVR entitled *'A safety re-evaluation of the AVR pebble bed reactor operation and its consequences for future HTR concepts.'* believes that approximately 100 kilograms of graphitic dust containing up to 700 ppm of Sr-90 accumulated in the primary circuit – posing a risk of widespread environmental contamination in case of an accident or upon decommissioning or maintenance.

The document entitled "PBMR – a safety review" distributed by the PBMR Pty Ltd[23] contains the following statements:

*"Pebble bed HTR's produce dust due to the continuous movement of pebbles in the core and in the fuel-handling system. This dust carries with it fission products that migrate from the coated particles into the matrix graphite of the fuel pebbles."…………*

*"Dust did not receive much attention in the early German programme. As the AVR's operating life was expected to be only three to four years, not much work was initially done on dust production."…….*

*"For dust generated and deposited around the system, some of the dust can be expected to be resuspended for larger depressurisation accidents. Minimisation of dust and activity is therefore a design and operational priority for the DPP. Provision is made in the design to remove dust in normal operations.*

*"PBMR has embarked on an extensive programme to both predict dust production [2] and distribution and augment these with selected examinations of AVR. As a first step, PBMR engaged FZJ in a joint effort to examine sample components removed from the AVR during decommissioning and analyse dust*

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[20] Environmental Impact Assessment Specialist Study : Radiological Safety and Health June 2008 p 72
[21] EIAR parag 3.5
[22] Julich Forschung Zentrum ("JFZ") http://hdl.handle.net/2128/3136/
[23] http://www.pbmr.com

*adhering to component surfaces. The first experiment, reported in [3], was mainly an exercise to establish the methodology to be used in collecting and analysing the dust samples. This step revealed some interesting facts. Dust could not be collected from the sample surface without using brute force and scraping it with a knife. (See Figure 2). The surface layer was also much thicker than would have been expected from a monolayer, which is predicted using general dust deposition theory. This indicates a possibility that the dust bakes to the surface under long-term operational conditions. This cannot be modeled using data obtained from experiments where settling or bonding conditions are not explicitly included.*

*Experiments are still in progress on other pipes and components and will produce data to be used, among others, in planning PBMR-specific dust adhesion and resuspension experiments. Initial analysis also confirms a high loading of Cs and Sr in the dust relative to the plate, out on the metallic surfaces. This means that if dust can be removed from the system by on-line filtration or cleaning, or be filtered out in a depressurisation event, most of the long- lived nuclides can be removed from the source term."*

The fact that PBMR has "embarked" on an extensive programme to predict dust production demonstrates that they are concerned about how much dust could accumulate and need to know more information. The first experiment, reported in [3], was mainly an exercise to establish the methodology to be used in collecting and analysing the dust samples, further study is necessary before there can be certainty.

Thus, statements made by PBMR Ltd. om reveal the following gaps in knowledge:

(i) They recently stated:*: "This step revealed some interesting facts …. the surface layer was also much thicker than would have been expected from a monolayer."*

This means that there is as yet no explanation for how thick was the layer of dust that they found.

(ii) They recently stated: *"Experiments are still in progress on other pipes and components and will produce data to be used, among others, in planning PBMR-specific dust adhesion and resuspension experiment."*

This indicates that the results of these experiments would comprise gaps in knowledge relating to the potential impact of the proposed PBMR DPP.

(iiii) They recently stated*: "Initial analysis also confirms a high loading of Cs and Sr in the dust relative to the plate out on the metallic surfaces. This means that if dust can be removed from the system by on-line filtration or cleaning, or be filtered out in a depressurisation event, most of the long- lived nuclides can be removed from the source term." ."*

The use of the word 'if' indicates what the issue of whether dust can be removed from the system by on-line filtration or cleaning, or be filtered out in a depressurisation event, is uncertain and yet another gap in knowledge.

***b) Eskom does not know why the AVR ran hotter than predicted or how hot sections of the PBMR DPP would get.***

It is not contested that the core temperatures of the AVR ran much hotter than predicted and that migration of certain fission products through the coating of the particles is temperature dependant. The document *"PBMR – a safety review,"* contains the following statements regarding temperature.

*"In the THTR, the fuel temperatures were not a concern as the gas outlet temperature was 750°C, which yields correspondingly low maximum fuel temperatures. In contrast, the AVR operated consistently with planned outlet temperatures above 850°C and long periods at 900 and 950°C. It is well known that migration of selected metallic fission products through the coating of the particles is very temperature dependent. At elevated temperature there will be increased fission product releases from intact fuel particles and consequent increases in the circulating and plated out activity of the primary circulation system. ....*

*"There was also apparently no consensus on the reason for the much higher temperatures observed from the melt wire experiments. Both the core geometry (noses extending into the core) and core bypass flows were thought to be contributors. To address these questions, PBMR has embarked on a programme to analyse the AVR using the available data on construction and operation to clarify understanding of high core temperatures. Preliminary results are presented in Section 6 and in [5]. The conclusion reached as reported in [5], is that given knowledge of the geometry, bypasses and core neutron power can be well modelled to explain the observed data. For the PBMR DPP an intensive and ongoing programme to reduce core bypasses in the graphite reflector designs was undertaken. Particular care was taken to feed the bypass flows back to the core at the elevation where the maximum operating fuel temperatures are found. This is confidently expected to eliminate the problem of unknown bypasses which plagued both the AVR and the THTR operation. Deliberate bypasses in the wall of the centre reflector serve to cool the reflector and the hottest fuel in the lower part of the core. The software and modeling used to enable this design is described in [6]."*

Thus, statements made by PBMR Pty Ltd. reveal the following gaps in knowledge:

(i) They recently stated: *There was also apparently no consensus on the reason for the much higher temperatures observed from the melt wire experiments.*

COMMENT: The absence of a consensus for why the AVR ran so hot is a critical gap in knowledge: a scientifically valid model for predicting core temperatures in pebble-bed HTRs.

(ii) They recently stated: *"To address these questions, PBMR has embarked on a programme to analyse the AVR using the available data on construction and operation to clarify understanding of high core temperatures."*

COMMENT: The fact that PBMR has "embarked" on a programme to find out why the AVR ran so hot indicates that they are concerned about the issue and need more information.

(iii) They recently stated: Preliminary results are presented in Section 6 and in [5].

COMMENT: The investigation is not nearly finished. Reference 5 is the Reitsma et al. report that was presented to the 4th International Topical Meeting on High Temperature Reactor Technology in Washington D.C. earlier this month.

(iv) They recently stated: "*For the PBMR DPP an intensive and ongoing programme to reduce core bypasses in the graphite reflector designs was undertaken. Particular care was taken to feed the bypass flows back to the core at the elevation where the maximum operating fuel temperatures are found. This is confidently expected to eliminate the problem of unknown bypasses which plagued both the AVR and the THTR operation."*

COMMENT: Again, this is hypothetical statement. If this "ongoing" program to redesign the proposed PBMR DPP does not eliminate the problem of unknown bypasses, then hotter than expected temperatures could again plague the operation of the PBMR DPP (but at a much greater scale – 400 MW v. 15 MW in the case of the AVR).

c) ***Eskom does not know how much the individual fuel pebbles would "leak" radioisotopes under "normal" conditions***

Figure 11 in the paper by Stoker et al "PBMR RADIONUCLIDE SOURCE TERM ANALYSIS VALIDATION BASED ON AVR OPERATING EXPERIENCE" presented by PBMR Pty Ltd. to the 4th International Topical Meeting on High Temperature Reactor Technology in Washington D.C. earlier this month includes data which throws into question the adequacy of assumptions of the draft EIAR that relate to radiological safety and health. For example, Appendix AL, the Specialist Study: Radiological Safety and Health, contains, in section 3.4.3, assumptions relating to "anticipated operational occurrence releases of radioactive materials to the environment." These assumptions involve calculations of radioisotope releases from regularly scheduled maintenance outages. However the dataset about what happened at the AVR that PBMR does not contest throws into question these assumptions about "anticipated operational occurrence releases of radioactive materials to the environment." If the PBMR winds up as dusty and hot as the AVR, then "anticipated operational occurrence releases of radioactive materials to the environment " assumed in the draft EIAR report are no longer valid.

Debates concerning these issues have been aired in the public domain in conferences around the world for many years (See annexure "B" hereto).[24] Media reports have confirmed that the safety case is still being considered and is not finalized yet, and this includes the consideration of whether secondary containment should be required.[25]

However the uncertainties regarding safety issues highlighted in these two reports have not been placed before the decision maker, contrary to the requirements of environmental and administrative law. As such the EIAR fails to place relevant information before the decision maker and is legally deficient. Should it proceed on this basis the authorization will be reviewable.

### *1.6 Failure to consider mitigation measures*

Paragraph 3.14 of the EIAR is important in that it sets out certain design goals for the PBMR DPP, which may not yet have been achieved, but which "must ensure that significant fuel damage is impossible under any conditions that can be predicted".

> "*The primary intention of the PBMR DPP is to allow for the performance testing of the technology in a controlled environment.*"[26]

[24] For example see Proceedings of the 3rd International Topical Meeting on High Temperature Reactor Technology October 1-4, 2006, Johannesburg, South Africa .AVR EXPERIMENTS RELATED TO FISSION PRODUCT TRANSPORT. At an earlier conferences in October 2001, G.A. Clapisson of the NNR travelled to the U.S. to attend a workshop about the safety of high-temperature gas-cooled reactors (HTGRs, of which the PBMR is one design). Dr. Dana Powers of the NRC Advisory Committee on Reactor Safeguards attended the workshop and presented a report of his views and those of other experts who attended. Details of these views were submitted by Earthlife Africa to the first EIAREIARREIARRR on the PBMR DPP and are annexed hereto marked Annexure B .

[25] Steve Lennon, Eskom, report in the Cape Times 20 September 2008

[26] Executive summary page 2

Because the PBMR DPP design is not yet final, and the enhanced safety claims of the PBMR have not yet been proven, it is not yet possible to propose appropriate mitigation measures. Statements as to the appropriate mitigation measures are premature.[27] The fact that the EIAR cannot at this stage determine or confirm appropriate mitigation measures proposed by the NNR means that authorization at this stage would comply with the legal requirements for EIAR's.

### *1.6.1 Legal Requirements in regard to the mitigation of impacts*

a) Section 24 (4) of the NEMA requires:

*b)*

*"(c) the investigation of mitigation measures to keep adverse impacts to a minimum."*

b) Regulation 8[28] which concerns requirements for the environmental impact report states:

"*the environmental impact report must contain a description of each alternative, including particulars of the possibility for mitigation of each identified impact".*

b) The EIAR report also states :

*"In terms of NEMA the commitment to sustainable development is evident in the provision that "development must be socially, environmentally and economically sustainable and requires the consideration of all relevant factors". NEMA also imposes a duty of care which places a positive obligation on any person who has caused, is causing or is likely to cause damage to the environment to take reasonable steps to prevent such damage. In terms of NEMA's preventative principle, potentially negative impacts on the environment and on people's environmental rights (in terms of the Constitution of the Republic of South Africa) should be anticipated and prevented and where they cannot be altogether prevented they must be minimised and remedied in terms of "reasonable measures".*[29]

### *1.6.2 Findings of the EIAR*

The findings of the EIAR conclude that there are no environmental fatal flaws that should prevent the proposed project from proceeding, provided that the recommended mitigation and management measures are implemented impacts. Mitigation measures are not spelled out in detail but it is clear from the EIAR and press reports that the issue of secondary gas tight containment is not recommended.[30]

The EIAR also states that during the commissioning and operational phases the impact of gaseous emissions on the environment during accident conditions was identified as an impact of low significance both before and after mitigation. It was argued that as long as the relevant mitigation measures are implemented no substantive risk to human health and safety have been identified.[31]

### *1.6.3 The conclusions of the report relating to mitigation are premature*

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[27] While the AVR reactor had secondary containment, Earthlife Africa was advised by Eskom in the meetingof 15 October 2008 that secondary containment would not be required for the PBMR DPP because it was a "demonstration " model unlike the AVR which was a "test" model.

[28] GNR 1183 of 5 /9/97

[29] EIAR p 19

[30] see footnote 16 and 18 above

[31] Executive Summary page 17

The EIAR fails to produce the Probabilistic Risk Assessment and Safety Assessment Report despite repeated requests to the consultants and so preventing the public from making inputs to possibly challenge these conclusions.[32] Moreover these documents have not yet been finalized. In their response to our clients requests for these documents the following advice was received from Eskom's consultants:[33]

> *You have requested a copy of "the Probabilistic Risk Assessment (PRA) referred to in the EIAR". In conducting the Air Quality Study, the specialist took into account the relevant minimum requirements stipulated by the National Nuclear Regulator (NNR) relating to radiation dose and risk to the public. These minimum requirements are contained in a NNR Requirements Document RD-0018 titled "Basic Licensing Requirements for the Pebble Bed Modular Reactor". However, the Requirements Document RD-0018 stipulates all the requirements that must be met for a nuclear installation licence, and thus contains more requirements that what was taken into account for the Air Quality Study. In particular, RD-0018 refers to requirements regarding probabilistic risk analysis, and which must be met in the application for the nuclear installation licence. The PRA that will be developed will thus form part of the Safety Analysis Report that will be submitted to the NNR at a later stage. The Air Quality Study did not reference a PRA, since such a document has not yet been completed and was not made available to the air quality specialist for his evaluation.*
>
> *You have also requested the Safety Analysis Report. This report, which is being prepared for submission to the NNR for the nuclear installation licence application is also not complete. Sections from relevant draft chapters that could provide information for the Radiological Waste Management Study were made available to the specialist, who then extracted relevant information from these sections. Arcus GIBB has forwarded your request to Eskom for the sections that were made available to the specialist. Eskom and PBMR (Pty) Ltd will confirm that there is no commercially sensitive information in these sections prior to approving thEIAR release. Arcus GIBB currently awaits this response.*

It is clear from this letter that the EIAR for the PBMR DPP is based on design and safety *assumptions* rather than a final design, and that the safety analysis has not yet been completed. The enhanced safety claims of the PBMR technology have not yet been proven.

A demonstration plant is required to verify the functional integrity of the plant.[34]

> "*The PBMR design is aimed at achieving a plant with a possible radiation hazard well below that currently of the Koeberg Nuclear Power Station. <u>Should this be demonstrated</u> to be possible by the PBMR DPP, it would reduce the impacts associated with exclusion zones and the restrictions on development within these zones.*
>
> *The combination of active and passive safety systems envisaged by the PBMR which are also designed to ensure that the requirements are consistent with the As Low As Reasonably Possible (ALARP) principle."*

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[32] Requests for the safety report were made to the consultants in e-mails dated 25 and 29/09/09, and 06 and 08/10/08.The applicant undertook to make available excerpts from the report but failed to do so. These were then requested in the meeting with the applicant on 15/10/2008. To date it has failed to provide these reports.
[33] Email dated 9/10/08
[34] Executive Summary page 6 final paragraph

It is not possible to predict with certainty whether the plant will perform as is hoped without demonstration.

> *"Although conceptual or theoretical models can and indeed have been used to predict these aspects (functional integrity and commercial performance of the plant) the level of activities required to inform an investment of this complexity demands that a demonstration facility be constructed."*[35]

It is stated emphatically in the Executive Summary that:

> "*informati on which is necessary to inform whether the PBMR is techno-economically feasible, such that it can be compared against other power generation technologies cannot therefore be obtained through any other means other than the construction and operation of a demonstration facility."*

Inherent in these statements then is the argument that without constructing the technology its functional integrity and all the aspects about it which at this stage are assumptions that remain unproven and uncertain. So too then are claims as to its enhanced safety. Conclusions as to the likelihood of accidents and catastrophic emissions cannot be drawn until the plant is built. To build a plant of this nature without taking steps to ensure that there is no breach of containment would violate the duty of care principle of NEMA.

It is submitted that the EIAR report recommendation of limited mitigation measures is premature and based on inadequate information. As such the recommendation is in violation of the PAJA section 6(e)(iii) requirements that all relevant considerations should be placed before the decision maker. Should the report fail to rectify these deficiencies the authorization will be unlawful.

### *1.7 The report fails to evaluate all potential impacts.*

The report fails to consider the consequences of an accidental or abnormal release of significant quantities of radioactive material as required by the Plan of Study which states that the DEAT will make the final decision on radiological matters relating to the EIAR.[36] This requirement was amplified in the DEAT letter of 25/8/2008. (see parag 1.2 above)
The EIAR report states:

*"For all Beyond Design Base Accidents the public doses demonstrate compliance with the Design Base Accidents regulatory dose limit.The potential radiological impact during Accident Conditions is thus considered to be of low significance and localised, with the highest impact close to the facility and the impact listens further from the facility".*[37]

The Radiological Classification Document[38] of the Plan of Study for the EIAR requires a description of the possible outcomes and mitigation measures of each "creditable" failure scenario. This requirement implies that the report must consider the impacts of any credible

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[35] Executive Summary page 7 first paragraph
[36] plan of study p 6-2
[37] Environmental Impact Assessment Specialist Study : Radiological Safety and Health June 2008 p 72
[38] Annexure F to the Plan of Study

abnormal emission including one which could result in a significant accidental release of radiation, ie a catastrophic incident.

It is submitted that it is not possible to describe such possible outcomes on the basis of a nuclear reactor which based on a design concept rather than a final design, which is the case currently with the PBMR DPP.

Moreover it was stated by the applicant at the meeting with between Earth life Africa and Eskom and its consultants on 15 October 2008 that this issue has been excluded from the EIAR by virtue of a co-operative agreement between the DEAT and the NNR, as inter alia the safety case has not been completed yet. This statement has the following practical implications:

a) the applicant intends that DEAT will, in certain circumstances, rely on decisions to be made by the NNR, contrary to the requirements of the Plan of Study ;
b) The NNR will consequently become the final decision-maker in respect of certain issues that are relevant to the making of a decision in terms of the EIAR process.

The decision-making process envisaged in the EIAR does not comply with sections 24(7) and 24(8) of the National Environmental Management Act, 107 of 1998 and the principles of administrative justice in the following respects:

It allows for unauthorised delegation of the DEAT's decision-making functions to the NNR and requires the DEAT to "act under dictation" of the NNR;

It requires the DEAT to make a decision without considering material facts in contravention of section 6 of the Promotion of Administrative Justice Act ;

It is procedurally unfair in that it is unclear how interested and affected parties ("I & APs") will be able to comment on the process when under consideration by the NNR.

In conclusion, it is our submission that the EIAR is legally deficient for the reasons set out above.

Compare for example the approach of the UK Health and Safety Executive regarding the licensing procedures for new nuclear reactors.[39] The HSE propose a two phase process: the first phase would be a Generic Design Assessment which is the HSE's Nuclear Installations Inspectorate's (HSE NII) assessment of the safety case for generic design, leading to the issue of Design Acceptance Confirmation if the outcome is positive. The second phase, the nuclear site licensing is the HSE NII's assessment of the application for a nuclear site license and is therefore site, reactor type and operator specific. There is no guarantee that phase 1 will lead to successful Design Acceptance. This will depend on whether the design and submissions meet HSE standards and expectations. Similarly a positive Design Acceptance Confirmation does not guarantee that a subsequent Phase 2 licensing application will be successful, as the latter phase covers wider issues.[40] This is the reverse of the process being currently followed in South Africa in respect of the PBMR DPP and which we submit is contrary to SA administrative and environmental laws.

The EIAR report is required to evaluate all actual and *potential* impacts of the activity, operating under abnormal and normal conditions. It is submitted that the EIAR cannot evaluate the potential impacts of a nuclear reactor which is not based on a design that is ready to be built and hence the EIAR is unable to comply with NEMA section 24(4)(b).

[39] Health and Safety Executive: New Nuclear Power Stations Generic Design Assessment Guidance to Requesting Parties, 2008 page 4. See http://www.hse.gov.uk/newreactors/latest.htm?ebul=newreactor/09-October-2008/

[40] id p 7

## B WASTE ISSUES

### 1. *PBMR Storage and Disposal of Radioactive Waste: Failure to Adequately Assess Waste Impacts*

The draft Environmental Impact Report (EIAR) Annexure OA: Specialist Study of Radioactive Waste Management provides an overview of the characteristics of the radioactive waste that will be generated by the PBMR DPP, which includes gaseous, liquid and solid radioactive waste. In addition to the annexed Specialist Study of Radioactive Waste Management, the Scoping Report and the draft EIAR raise the issue of radiological waste in a number of chapters[41].

It is a statutory requirement that high level radioactive waste (HLRW) be subjected to an environmental impact assessment. The regulations to the Environmental Conservation Act (ECA) of 1997 identify the construction, erection or upgrading of nuclear reactors and facilities for the storage of nuclear fuels and waste as an activity that may have a substantial detrimental effect on the environment, and which therefore require an environmental impact assessment (EIAR)[42].

As already raised in the LRC response to the PBMR Plan of Study, the draft EIAR uses a descriptive approach to what is supposed to be an evaluative and analytical exercise. The draft EIAR proposes a Waste Handling System to handle, store and discharge low and intermediate level liquid and solid waste (LILW) generated, and a Fuel Handling and Storage System for the Spent Fuel high level waste (HLW)[43]. The Annexure OA to the EIAR includes a description of the type of radioactive waste to be generated by the PBMR DPP, a description of the manner in which all radiological waste is likely to be managed for the PBMR DPP. The document also includes a description of international trends and policies with respect to the disposal of high-level radioactive waste, a description of the South African policy and strategy on high-level radioactive waste and how this policy compares with international policies, and a description of the proposed manner in which high-level radioactive waste from the PBMR DPP will be managed on-site. Analysis of the socio-economic and environmental effects of the storage of the radioactive waste on the land, on the surrounding communities of the proposed PBMR DPP are not addressed throughout the document. The EIAR mentions some possible impacts or challenges related to radioactive waste management generally in the abstract but not specifically in relation to PBMR project[44]. The Final Plan of Study (POS) in May 2008 for EIAR identified the radiological impacts associated with the management of solid, liquid and gaseous radioactive waste.

In response to the POS from May 2008, the DEAT has required that PBMR articulate clearly and simply in the EIAR the potentially significant negative impacts of the PBMR DPP on the receiving environment and of the receiving environment on the PBMR DPP, at alternative sites, as well as the potentially significant environmental risks associated with the PBMR DPP[45]. The EIAR does not include a proper evaluation of the economic, social, safety and other impacts of a significant increase in the generation of waste from the PBMR DPP.

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[41] See EIARRR chapter 3.10, 3.11, 3.12, 5.4.4., 3.14, 4.4, 5.3.8, 6.2.2, 6.2.4, 8.3 .8, 9.3.2, 9.4.5, 10.1, 10.4.2, 10.4.3, 11.4.2

[42] GN R1182 and GN R1183 to the ECA.

[43] PBMR EIAR Annexure OA p37.

[44] PBMR EIAR Annexure AO p82.

[45] DEAT letter, 25 August 2008, recommendation 3.

While the draft EIAR does mention the alternatives considered for the storage of Koeberg Nuclear Power Station (KNPS) Spent Fuel, the draft EIAR fails to include a description of the extent and significance of environmental impacts associated with alternative storage sites or methods for the PBMR, and also fails to include particulars on the possibility for mitigation of each identified impact.

### *2. Low and Intermediate Level Waste (LILW)*

The EIAR Impact Analysis Chapter concludes that the cumulative socio-economic impacts on radiological safety and health on the Vaalputs waste disposal site will be low, without providing additional details as to how it came to this conclusion and without addressing the disposal of HLRW[46]. All low and intermediate level waste (LILW) generated at the KNPS and the PBMR DPP will be disposed of at the national radioactive waste disposal facility at Vaalputs, in accordance with the RWMPS. The EIAR maintains that although this may result in direct and indirect impacts to humans and biophysical environment, the dose humans may receive from the disposal of radioactive waste would not challenge the dose limit provided for in the safety standards for regulatory practices published in the Government Notice R. 388. Those safety standards require that the annual effective dose limit for members of the public from all authorised actions is 1 mSv, while the dose constraint applicable to the average member of the critical group within the exposed population is 0,25 mSv per year specific to the authorized action. The EIAR maintains that the combined impact for waste disposal operations at Vaalputs would not challenge the dose limit of 1 mSv per year.

### *3. High Level Radioactive Waste*

The bulk of the HLRW to be produced by the proposed PBMR will consist primarily of the spent fuel pebbles[47]. According to the EIAR, a 165 MWe PBMR module will generate a nominal 35 tons of spent fuel pebbles per year[48].

While HLRW claims to be low in volume compared with other radiological wastes produced by nuclear power plants, it contains the highest radioactive content[49]. According to a United Kingdom report to the House of Lords by a Select Science and Technology Committee:

*'During the first thousand years after its production, the radioactivity of HLRW falls by a factor of about one thousand as the shorter-lived radionuclides decay (particularly caesium-137 and strontium-90, which have radioactive half-lives of about 30 years). Over about the next ten thousand years the activity of the HLW[50] decreases by about another factor of ten, as americium-241 (half-life of about 430 years) decays. After this, the activity of HLW decreases more slowly until around three million years, when the quantities of radionuclides such as neptunium-237 (half-life of 2.1 million years) and caesium-135 (half-life of 2.3 million years) begin to fall substantially.'*[51]

[46] PBMR EIAR, p10-38.
[47] PBMR EIAR Annexure OA p34.
[48] *Id*. The KNPS generates about 32 tons of spent fuel each year, which could add up to 1,280 tons over a 40 years. *Id*. p34
[49] According to a United Kingdom (UK) Committee on Science and Technology's (10 March 1999, *Management of Nuclear Waste)* Third Report to the House of Lords, 90% of the radioactive content of all waste in stock in the UK in 1994 consisted of HLRW. Available at:
http://www.parliament.the-stationery-office.co.uk/pa/ld199899/ldselect/ldsctech/41/4102.htm
[50] High Level (radioactive) Waste
[51] Select Committee on Science and Technology, 10 March 1999, *Management of Nuclear Waste*, Third Report, p4, available at:

It is also pointed out in the report that 'safety assessments of HLW disposal (see, for example, the European PAGIS study) indicate that potential risks to humans may still be significant for hundreds of thousands of years'[52].

### *4. Long-Term Radioactive Waste Management*

DEAT has accepted the PBMR Plan of Study for EIAR dated 9 May 2008 for the PBMR subject to conditions including that "the capacity and capability of institutions to manage radiological waste generated by the PBMR DPP is addressed."[53] The draft EIAR does not adequately address the capability of PBMR's long-term management of HLRW to prevent potential risks to future generations.

There is no final disposal solution for high-level radioactive waste in South Africa. The draft EIAR states that the prevailing opinion internationally is that if spent nuclear fuel is to be disposed of as radioactive waste, deep geological disposal is the appropriate option[54]. If the integrity of spent fuel cannot be assured, then the geological disposal option would not give assurance that HLRW will not reach or escape into the environment during the course of the millions of years and the HLRW may pose a significant safety risk to humans.

The DME's 2005 Radioactive Waste Management Policy and Strategy (RWMP) designates Vaalputs as the National Disposal Site for low and intermediate level waste, but, however, acknowledges that the government is still in the process of selecting a site for long-term high level waste management. Countries that have high-level radioactive waste and spent fuel generally agree that deep disposal in geological formations is a scientifically acceptable option[55]. The RWMP states the Used Nuclear Fuel should continue to be stored in authorised facilities within the generator's sites, while the South African government initiates investigations into the best long-term option[56]. The document makes it clear that this practice is not sustainable indefinitely[57]. The RWMP also acknowledges that "storing above ground indefinitely may result in an undue burden on future generations"[58].

The EIAR proposes that all high-level waste generated by the PBMR DPP will be stored within the reactor building of the facility according to the NNR requirements. The EIAR indicates that HLRW in the form of spent nuclear fuel will be stored in a Sphere Storage Subsystem (SSS) of the Fuel Handling and Storage System (FHSS) which has sufficient capacity to store all the spent fuel produced during the life of the plant[59]. These fuel storage pools are 18.5 m deep and are located below ground level inside the reactor building[60]. The EIAR also points out that spent fuel can remain on site for another 40 years after the PBMR has been decommissioned, before being transported to a HLRW disposal facility yet to be established.

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http://www.parliament.the-stationery-office.co.uk/pa/ld199899/ldselect/ldsctech/41/4102.htm
[52] Ibid.
[53] DEAT letter, 25 August 2008, recommendation 8.
[54] PBMR EIAR Annexure AO, p.46.
[55] United Kingdom Department of Environment, Food and Rural Affairs website, Available at http://www.defra.gov.uk/; Nuclear Energy Agency (NEA) OECD (www.nea.fr) US Environmental Protection Agency www.epa.gov
[56] RWMP p26.
[57] *Id.*
[58] *Id*. p27.
[59] PBMR EIAR Annexure OA p56.
[60] *Id*. at p57.

The EIAR fails to assess what impact of Spent Nuclear Fuel produced by the PBMR will have in South Africa. As already mentioned above, according to statutory requirements an EIAR would have to be conducted prior to any geological or other repository being approved. The feasibility of deep geological disposal has not been proven beyond reasonable doubt in South Africa. According to a recent white paper released by the United Kingdom's Department of Environment, Food and Rural Affairs government, a site assessment for implementing geological disposal of radioactive waste should take into account the following proposed criteria: "geological setting, potential impact on people, potential impact on the natural environment and landscape, effect on socio-economic conditions, transport and infrastructure provision, and cost, timing and ease of implementation"[61]. Such a comprehensive assessment would inevitably take a number of years.

A cautious approach to the issue of HLRW disposal has been recommended by the United Kingdom's Royal Commission on Environmental Pollution, which stated that:

> *'there should be no commitment to a larger programme of nuclear fission power until it has been demonstrated beyond reasonable doubt that a method exists to ensure the safe containment of long-lived highly radioactive waste for the indefinite future'.*[62]

It is submitted that it is irresponsible of the applicant to want to produce more HLRW prior to the comprehensive safety assessment having been completed. A proper application of the preventative and precautionary principles in section 2 of NEMA[63] suggests that DEAT should refuse the application for the demonstration module PBMR until the comprehensive safety assessment has been completed and a geological disposal has been proven as an appropriate and sustainable disposal option for HLRW.

Even if the method of disposing of HLRW in a deep geological repository is proven feasible in South Africa, the legal requirements for an EIAR would require the consideration of alternatives. At the very least this should include an investigation of the option of indefinite storage on or near the surface[64]. It is submitted that this option would enable HLRW to be monitored for leaks or deterioration of spheres, casks or barrels, and would have the advantage of affording future generations the option of considering possible future technological advances in deciding how they wish to dispose of the burden of committed[65] HLRW[66]. Until such alternatives have been

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[61] Managing Radioactive Waste Safely: A Framework for Implementing Geological Disposal (June 2008) White Paper by DEFRA, BERR and the devolved administrations for Wales and Northern Ireland, 7.26.

[62] Quoted in Report to the House of Lords by Select Committee on Science and Technology, 10 March 1999, *Management of Nuclear Waste*, Third Report, p2, available at: http://www.parliament.the-stationery-office.co.uk/pa/ld199899/ldselect/ldsctech/41/4102.htm

[63] The preventative principle finds expression in section 2(4)(a)(iv) of NEMA, which states that sustainable development requires the consideration of all relevant factors, including that waste is avoided, or where it cannot be altogether avoided, is minimized and reused or recycled where possible and disposed of in a responsible manner. The precautionary principle finds expression in section 2(4)(a)(vii) of NEMA, which states that sustainable development requires the consideration of all relevant factors, including that a risk-averse an cautious approach is applied, which takes into account the limits of current knowledge about the consequences of decisions and actions.

[64] Along with geological disposal on land, the option of indefinite on or near the surface storage is considered by the Select Committee on Science and Technology as one of the 2 main options still under consideration. See Report to the House of Lords by Select Committee on Science and Technology, 10 March 1999, *Management of Nuclear Waste*, Third Report, available at: http://www.parliament.the-stationery-office.co.uk/pa/ld199899/ldselect/ldsctech/41/4102.htm

comparatively assessed as required by regulation 8(b) of GN R1183, any decision to grant authorization for the building of the demonstration module PBMR would be unlawful.

Until the economic and scientific uncertainties of establishing a HLRW disposal facility in South Africa have been resolved, a risk averse approach must be adopted by DEAT[67]. This approach must take into account the limits of current knowledge and the consequences of authorizing an activity that during its lifespan will produce HLRW that cannot presently be disposed of.

### *5. There are no regulations governing safe storage of HLRW*

The PBMR EIAR states that the principles for radioactive waste management in South Africa may be found in the RWMP of 2005[68]. The RWMP however only sets out policy issues and responsibilities, but does not include actual requirements for the management of radioactive waste. Section 36 of the National Nuclear Regulator (NNR) Act 1999 requires the Minister, on recommendation of the board, to make regulations regarding safety standards and regulatory practices. Section 45(1)-(2) of the Nuclear Energy Act 46 of 1999 stipulates that the authority over the management and discarding of radioactive waste and storage of irradiated nuclear fuel is vested in the Minister of the Department of Minerals and Energy (DME) who may make regulations regarding the manner of discarding of radioactive waste and irradiated fuel.

The Minister of DME has not made any such regulations to date, nor has she published such proposals in the Gazette for comment. Section 4.6.2 of the NNR Government Regulations 388 from 2006 states that the safety of long-term radioactive waste storage options must be assured for the envisaged period of storage, but does not set detailed regulations regarding the management of long-term radioactive waste storage. These Government Regulations from 2006 have, however, set the dose constraints for radioactive exposure, as mentioned above.

Before any such regulations are made, the Minister of DME is statutorily required to publish a notice in the *Gazette* inviting the public to comment on the proposed regulations, and to consider those comments[69]. PBMR should not be granted permission to proceed with an activity that will produce HLRW until the Minister has made these regulations, and until the Minister has received comment from the public and has considered the comment.

The National Radioactive Waste Management Agency Bill currently before Parliament provides for the establishment of a National Radioactive Waste Management Agency to manage radioactive waste disposal on a national basis. Section 7 includes among its functions (c) "to develop radioactive waste acceptance and disposal criteria in compliance with any applicable regulatory safety requirements and any other technical and operational requirements", (d) "to assess and inspect the acceptability of radioactive waste for disposal and to issue radioactive waste disposal certificates", as well as (h) "to define and conduct research and development aimed at finding solutions for long-term radioactive waste management." This Bill has not yet been accepted by Parliament and no radioactive acceptance and disposal criteria has been set.

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[65] Waste that is already being produced by the existing Koeberg NPP, and that the EIARRR states is being produced by other sectors of the economy like mining.

[66] In the context of the proposed PBMR, it is submitted that the most appropriate option for ensuring that future generations are not burdened with the problem or environmental consequences of the disposal of long-lived HLRW is the 'no go option'.

[67] As required by section 2(4)(a)(vii) of NEMA.

[68] PBMR EIAR Annexure AO p8.

[69] Section 54(4)(a)&(b) of the NEA.

## C ECONOMIC ISSUES
## THE REPORT FAILS TO PROPERLY CONSIDER THE DECOMMISSIONING COSTS

The scoping report and the DEAT letter of 25/8/2008 require the EIAR to consider the costs of decommissioning. As is clear from paragraph 1.5 above, certain issues pertaining to safety have not yet been resolved, and these issues may have a direct bearing on the costs of decommissioning. It has been stated that the costs of decommissioning of the AVR were significantly increased as a result of issues relating to the fuel used[70] It is submitted that until uncertainties regarding the fuel and unresolved issues relating to levels of dust buildup and heat attained by the reactor have been resolved for the purposes of the proposed PBMR DPP it will not be possible to give accurate projections of decommissioning costs of the PBMR DPP. The EIAR is therefore premature and fails to place all relevant information, (which mayultimately be placed at the disposal of the DEAT, though it is not available presently) before the decision maker, in contravention of the requirements of PAJA section 6.

### *1. In amplification of the above we make the following submissions.*

The National Environmental Management Act, 1998 requires an analysis of the economic impacts of environmental developments in South Africa. Section 2(3) stipulates that the state should ensure that development must be socially, environmentally and economically sustainable;[71] while section 2(4)(i) requires that 'the social, economic and environmental impacts of activities, including disadvantages and benefits must be considered, assessed and evaluated and decisions must be appropriate in the light of such considerations and assessment". Such decisions must moreover be taken in an open and transparent manner and access to information must be provided in accordance with the law.[72] The assessment of environmental impacts in terms of NEMA must include the assessment of potential impact on the socio-economic conditions and the assessment of the significance of that potential impact.[73]

The Final Scoping Report for the proposed Pebble Bed Modular Reactor Demonstration Proposed Plant (PBMR DPP) set out in Section 7.3.2 the issues and concerns to be studied in the Environmental Impact Assessment, which included tourism impact assessment, assessment of the no-go option, decommissioning/dismantling. A list of "Economic Impacts" were also included among the environmental issues identified in the Final Plan of Study for the Environmental Impact Assessment (EIAR). The list included tourism impacts, the future economic pathways of the PBMR DPP with respect to potential costs and benefits to the country and the impacts related to decommissioning of the PBMR DPP.[74] Questions about the extent of the excess costs and who will bear these costs (taxpayers, electricity consumers or

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[70] Mark Hibbs, *Decommissioning costs for German Peblle Bed Reactor escalating*, NUCLEONICS WEEK, Vol. 43, No. 27, p7 (July 2002): *"according to officials from AVR GmbH attending a waste management conference in Tucson, Arizona in March 2000, they had seriously miscalculated what was involved in handling the spent fuel inventory from the reactor. "In most reactor decommissioning projects, the fuel is of little or no concern because defuelling has already been completed in the operational phace," they reported then. But for the pilot pebble bed unit with its graphite lead fuels spheres, "the fuel has blown to pieces all decommissioning planning so often optimistically presented at former meetings".*

[71] Principle 2(3).

[72] Principle 2(4)(k).

[73] NEMA section 24(7)(b).

[74] Final Plan of Study for PBMR DPP Environmental Impact Assessment, May 2008, 4-1.

private investors) have largely remained unanswered in the PBMR DPP Environmental Impact Report (EIAR).

Forecasts of the PBMR DPP's operating performance, operating cost and decommissioning cost appear implausibly optimistic. The Draft PBMR EIAR states that the "direct project cost relating to the demonstration power plant and pilot fuel plant, amounts to some R16 billion in June 2006 real terms."[75] The Draft EIAR claims that government revenue is to increase by approximately R977 million per annum as a result of construction of the PBMR DPP.[76] With regard to exports, the Eskom PBMR DPP EIAR claims that the project could contribute up to R8 billion to the local Gross Domestic Product (GDP) and R10 billion per year in exports, while creating about 57,000 direct and indirect jobs.[77] The report also estimates the total construction costs of PBMR on the country's GDP as approximately R7.3 billion which is almost 0.44% of the national GDP of South Africa for 2006.

During the period of 1999 to 2005, the estimated cost of the demonstration programme appears to have escalated by a factor of more than seven. According to Thomas, some of this is due to the inappropriate addition of the commercial fuel plant.[78] The estimated cost of the demonstration plant itself has increased by about 50 per cent, the cost of the pilot fuel plant has increased by a factor of nearly four. The overheads appear not to have been estimated in the 1999 forecasts. Until the detailed design is completed: equipment design development, for example on the turbine, has been carried out; design approval by the National Nuclear Regulator (NNR) is given; and the plant has actually been built, the cost estimates must be treated with scepticism. Experience with other nuclear projects shows these processes provide ample scope for further major cost escalation."[79]

The main factors that must be considered when determining costs include (1) cost of construction; (2) cost of capital; (3) operating and maintenance cost, including fuel supply and spent fuel disposal; and (4) decommissioning cost.[80] When including the commercial programme, additional factors such as the economic competitiveness of the PBMR and the likely world market and South African markets for PBMRs should be considered as well.[81] None of these factors can be estimated with any precision at this stage and the analysis of risk and who will bear the cost of poorer than expected performance is particularly important.[82]

### *2. Unresolved safety issues and economic impacts*

Any determination of costs related to both the operation of the PBMR DPP and its decommissioning are premature, as the safety measures of the reactor have not yet been

[75] Draft PBMR EIAR, p9-69; A.B.J. Dippenaar, PBMR DPP Socio-Economic Impact Assessment, EIARRR Annex AB, November 2007 (revised February and June 2008), 45.
[76] Draft PBMR EIAR, 9-69.
[77] *Id*. at p4-2.
[78] Steve Thomas, *The South African Nuclear Power Programme: Submission to the Portfolio Committee on Environmental Affairs and Tourism* (June 2007), 9.
[79] *Id*.
[80] *Id*. at 3; Greenpeace, *The Economics of Nuclear Power* (May 2007), 20-21.
[81] Thomas at 3.
[82] *Id.* at 6.

established. The costs of sufficient safety measures are particularly high in the case of pebble bed reactors, and it is doubtful that a safe and economic pebble bed reactor is achievable.[83]

The Draft PBMR EIAR claims that, *"PBMR's inherent safety is fundamental to the cost reduction achieved over other nuclear designs, as less safety systems are required and the plants ease of operability also reduces the need for large numbers of maintenance and operating staff."*[84] This is a questionable statement given the unresolved safety issues referred to in paragraph 1.5 above.

In the light of these unresolved safety issues, the precautionary approach requires that a risk averse approach be applied in the consideration of relevant factors in the EIAR and therefore that the economic impact of the cost of secondary containment on the PBMR DPP be considered in the EIAR. The report by R Moormann[85] calls for complementary secondary gas tight containment in order to achieve safe operation of pebble bed reactors and mitigate the safety risks. This issue is unresolved at this stage.[86] The costs of regulation and safety may increase the project costs significantly, in the light of such requirement.

The demonstration phase of the PBMR including the purchase of the demonstration plant could cost electricity consumers over the next 5 to 100 years in South Africa R10 billion, and R36 billion for the purchase of commercial units.[87] These figures, however, do not include the additional costs of decommissioning the demonstration plant and the commercial plants. According to a 2005 study cited by the Draft EIAR Financial Aspects Specialist Study, the decommissioning of the PBMR DPP would cost an estimated R1,508.79 million (including spent fuel management costs) based on 2005 rand values.[88]

This estimate for the decommissioning of the PBMR DPP is, however, premature. The Demonstration Plant will leave a substantial liability that will fall on South African public funds due to the need to decommission the plant and the associated facilities, and to pay for the disposal of the spent fuel. The Draft EIAR states that should the decommissioning philosophy be to return the sites to their natural state, and surface water impacts are widespread, extensive landscaping will be required to return the sites to their natural topography; reduce surface accumulation in areas previously free draining; promote surface water accumulation in natural wetland systems; remove any potential for contamination, siltation and/or inundation of natural systems; and reduce erosion risks.[89] The Draft EIAR acknowledges that the rehabilitation of impacted areas on which the PBMR DPP is located to pre-development levels or better is unlikely, and that parts of the plant are going to remain in place for some years after shutdown[90] (i.e. spent fuel storage).

Both the storage of spent fuel and the production of dust due to the continuous movement of pebbles in the core and in the fuel-handling system have the potential to increase the costs of decommissioning. The excess radioactive dust may contribute to the releases of radioactivity from the PBMR, that would also pose a risk of widespread environmental contamination in the case of an accident or upon decommissioning or maintenance. According to the PBMR Safety Review, PBMR has embarked on a programme to predict dust production and distribution and augment these with examinations of the AVR.[91] The first experiment conducted by PBMR

[83] *Id*. at 3.
[84] Draft PBMR EIAR, 4-2.
[85] Footnote 21 above
[86] Footnote 16
[87] Thomas, *supra* note 8, at 3.
[88] Draft PBMR Specialist Study: Financial Aspects, February 2008, Appendix AM, 13.
[89] Draft PBMR EIAR, 9-8.
[90] *Id*. at 9-18.
[91] PBMR: A Safety Review, at 4.

revealed that “dust could not be collected from the sample surface without using brute force and scraping it with a knife”, and that, “the surface layer was also much thicker than would have been expected from a monolayer”, which, “indicates a possibility that the dust bakes to the surface under long-term operational conditions”[92]. According to PBMR, experiments are still in progress to plan PBMR-specific dust adhesion and resuspension experiments.[93] This suggests that there is absolutely no certainty regarding the ability of a filtration or cleaning mechanism to remove the dust and most of the long lived nuclides, nor is it therefore possible to properly predict the costs associated with the process.

"The estimated decommissioning costs of the German AVR (often described as the reference design for the South African PBMR) had risen significantly by 2002, perhaps 20-fold, as the consequences of the operational history of the AVR became clear.[94] It was estimated in 2002 that the decommissioning cost could reach €490m (R7.5bn) for the 15MW prototype plant. The estimated costs are highly likely to have increased since then. German experts responsible for the decommissioning of the AVR at the time said that the AVR had the worst beta contamination of any nuclear installation in the world, and expressed concerns about the reactor’s spent fuel inventory of graphite-clad spheres.[95] In conclusion it appears that uncertainties regarding the AVR and what led to its increases in estimated decommissioning costs are highly relevant to the assessment of potential costs of decommissioning of the PBMR. If the PBMR were to become as badly contaminated as AVR, given that the PBMR is ten times the size of AVR, the decommissioning costs could be of the order R70bn. Since these are as yet unresolved any predictions as to decommissioning costs of the PBMR DPP made in the EIAR are premature and insufficiently informed and constitute a failure to place all relevant information before the decision maker in conflict with the requirements of PAJA section 6. The submission of the EIAR should therefore be deferred until all this highly relevant information is available for inclusion in the report.

Yours faithfully

**ANGELA ANDREWS**
**LEGAL RESOURCES CENTRE**

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[92] *Id*. at 5.
[93] *Id.*
[94] Mark Hibbs, *Decommissioning costs for German Peblle Bed Reactor escalating*, NUCLEONICS WEEK, Vol. 43, No. 27, p7 (July 2002).
[95] *Id.*

**Annexure “A”**

**Excerpts from the submission by Earhthlife Africa to the first EIA of the PBMR DPP**

## 5.1 Critique of Safety Impact Assessment

### 5.1.1 The degree of novelty in the proposed design, and the safety implications of the novelty of the proposed plant are not recognised in the EIR, leading to a gross underestimation of the safety risks associated with the proposed plant

The EIR provides the following motivation for the Project: “The purpose of the proposed Plant is to assess the techno-economic viability of the technology for South African and international application for electricity generation and other commercial applications.”[96] Thus the stated purpose is to assess of the technology of power generation based on the PBMR, and the economics of this method of power generation, and the interaction between these two factors.

The degree of novelty of the design is stated only in general terms in the EIR. For example, the EIR states:[97] “The reactor is based on the German AVR, Thorium High Temperature Reactor (THTR), High Temperature Module Reactor (HTR-Modul) and High Temperature Reactor (HTR) -100 designs. The basic design and the operating experience of these plants have been used in the design of the PBMR.” These statements imply that certain design details are different or may be different from the German designs referred to. It is not clear if the proposed reactor is the same size, or is designed to operate at the same temperatures and pressures and /or whether other design parameters are the same as the reactors referred to.[98] A further example that certain aspects of the design are novel: “The specialised gas cycle pipe design is based on the proven THTR-300 and HTR-Modul hot pipe technology. The design of the fuel handling and storage system is based partly on the THTR-300 reactor, in that the PBMR reactor also has a multi-pass fuelling scheme as well as on-line re-fuelling. Some aspects of the system are, however, unique to the PBMR design.” Thus there is an explicit and implicit recognition that the design differs significantly from previous designs. It is clear that some design innovations have yet to be tested. Hence the stated need for the construction and operation of a “demonstration” plant.

The EIR recognises that aspects of the design are new, and therefore have to be “demonstrated”. But key aspects of the safety performance of the new technology are stated

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[96] DRAFT ENVIRONMENTAL IMPACT REPORT FOR THE PROPOSED PEBBLE BED MODULAR REACTOR (PBMR) DEMONSTRATION PLANT AT KOEBERG IN THE WESTERN CAPE, Rev 4 (EIR) Executive Summary, p1

[97] EIR 2.2.2, p7

[98] It is noted that the AVR reactor was significantly smaller than the PBMR proposed - 15MW compared with 110MW, implying that a significant scale-up factor is involved. AVR, 1.3.2.1, p21

as proven facts rather than as novel designs that ***appear*** to be better based on theoretical calculations and, in some cases, limited experimental data, but that require validation and verification through extensive testing and operational experience. For example, the description of the design features of the plant include the paragraph "When PBMR fuel is without helium cooling, the fuel will not increase to temperatures that can result in significant fission product release. For normal and accident conditions without cooling, the fuel and fission products will be retained within a series of protective boundaries in the pebbles. In addition to ensuring the safety of the worker and the general public, this design feature enables the PBMR to be located near areas of high population."[99] This assertion of the absolute (or near absolute) safety of the PBMR system is stated as if, in the area of safety, absolute reliance may be placed on the calculated performance of the design. In addition, the stated key safety features are that "the fuel will not increase to temperatures that can result in significant fission product release" and "the fuel and fission products *will be retained* within a series of protective boundaries in the pebbles" [emphasis added] – thus the physical failure of the pebbles is *assumed* to be impossible. These statements rely of course on theoretical calculations, but the *assumption of perfect safety* implies not only that the design calculations are infallible, but that the pebble manufacturing process is infallible, and that it is thus unnecessary to even consider the possibility (and consequences) of the failure of the pebbles. No data (only summary conclusions) derived from the technological predecessors of the proposed design are presented to support such an absolute assertion of safety. The limited technical information contained in the DFR Public Report[100] shows that there is limited experience of the manufacture of the fuel spheres: "The design of modern HTGR is critically dependent on high-quality fuel. Hence, the most important goal in the improvement of the manufacturing process of the fuel element is to reduce the coated particle defect fraction and to minimize the uranium contamination." The DFR report reveals that: "Between 1968 and 1988 when it was decommissioned, the German NUKEM plant supplied more than one and a quarter million spherical fuel element to the AVR and the THTR plants." The estimated requirement for fuel sphere for the proposed Plant is 270 000[101] per annum. The 1.25 million fuel spheres produced in the earlier experimental plant should thus be seen in the context of a five years' supply to a single module, and one year's supply to the projected commercial system of five modules. As the AVR and THTR plants were experimental or developmental units, the pebbles were themselves subject to a development process. ("… continuous improvement of the fuel element design and manufacture were achieved before the fuel plant was closed"[102]). Indeed, because of the pebble development process, it may reasonable be inferred that pebble design and manufacturing changes were made during the course of the production of the 1.25 million spheres, and that the manufacturing experience of the pebble

[99] EIR, 2.2.2, p8
[100] REPORT ON THE PROPOSED DEMONSTRATION MODULE AND POTENTIAL COMMERCIALIZATION OF THE PEBBLE BED MODULAR REACTOR, Document No.: **011252-160, Revision 1** (referred to in this document as DFR)
[101] DFR, 2.2.4.1, p32
[102] DFR, 2.2.2, p31

design proposed for the proposed PBMR is considerably less that 1.25million pebbles quoted as produced during the entire 20 year development process.

The DFR also asserts (in relation to pebble manufacture) that excellent product performance was achieved. In relying on this earlier development work to assume "zero defect" for the manufacture of the pebbles, data should be submitted to show that the pebbles for the proposed PBMR are identical in all material respect to the pebbles used (or a subset of the pebbles used) in the AVR and THR plants, and all relevant data to demonstrate the reliability of the manufacturing process and quality assurance system, as experienced during the development phase. Specific details of the development history of the NUKEM pebbles, the failure modes and the conditions under which failure occurred during the various pebble development designs, and the number of pebbles produced of the same or essentially similar design as those proposed for the Project should be disclosed for public scrutiny. The data should be subjected to statistical analysis to demonstrate the actual reliability achieved, and the statistical power of this limited set of historical data to predict "zero defect" for the pebble manufacturing process. In any event, the fuel fabrication plant required appears to be significantly larger than previous designs; this scale up is itself a source of process risk in relation to the pebble manufacturing process, and hence the PBMR.

To assert and assume (from a safety analysis point of view) that a *zero* defect level will be achieved on a new fuel plant, from the outset, is unrealistically optimistic, and contrary to historical experience on novel technologies. Indeed, it is apparent that the technologies on which the proposed plant is based have not been incorporated into commercially proven power plants, a factor that in itself indicates that the operational data, even for those aspects of the design that are substantially similar to the predecessor reactor designs, is limited.

The implication of the novelty of the design is that not only the technical performance (capital cost, power output, availability, operating costs, maintenance requirements etc.) of the plant has to be demonstrated, but the safety performance as well. In a contradictory fashion, Section 19 of the EIR[103] states that "An extensive Test and Commissioning Programme demonstrates the performance of all Systems, Structures and Components (SSC) and materials important to safety." The physical integrity of the pebbles is clearly one of the factors ("materials") of importance to safety. But how will the Test and Commissioning Programme establish the limits of safe operation without risking an unsafe condition on the plant? Furthermore, beyond the initial Test and Commissioning Programme, a statistically valid conclusion as to the reliability of the pebble manufacturing process under actual conditions will again require extensive operating experience (post Comissioning), with the risk of failure during the period. Yet the design does not include a secondary containment structure for radioactive fission products that may be released under system failure

[103] EIR, 19.9, p213

conditions, based on the assumption that the design and construction of the pebbles ensures 100%safety, under all possible operating and test conditions. Until the safety features of the new design are demonstrated through extensive operational experience, *it is reckless to assume that the plant will invariably and under all possible (not only all foreseeable) circumstances perform in accordance with the design calculations.* The EIA/ EIR documentation includes phrases such as “No credible events will lead to the loss of fuel integrity”, “No operator intervention is required for several hours following any nuclear accident occurrences”[104] and “inherently safe”[105]. Similarly, the Safety and Security Chapter of the EIR states: “The Final Safety Design Philosophy (FSDP) is based on the premise that the fuel will adequately retain its integrity to contain radioactive fission products under normal and accident conditions and thereby allow radiological safety to be assured. This is achieved by relying on fuel whose performance has been demonstrated under simulated normal and accident conditions, and whose integrity will therefore not be compromised even under accident conditions.” As already noted, the full SAR has not been made available for public scrutiny, but the implication of these statements is that, in relation to this critical safety issue, a paper simulation of normal and accident conditions is sufficient to demonstrate the performance of the fuel. Similarly, the EIR Social Impact Report[106] states: “the Final Safety Design Philosophy (FSDP) for the PBMR has been based on the Defence-in-depth premise that the fuel will retain its integrity.” The total and repeated reliance on the absolute integrity of the *premise* “that the fuel will maintain its integrity” is in fact not a reflection of the defense-in-depth concept but a reliance on a single safety barrier.

These statements in fact reflect a *refusal* to consider in detail and in depth the simple question – what if the pebbles fail? – and therefore a refusal to consider the consequences of such a failure, and to design for the possibility of such a failure during the operation of the proposed prototype PBMR. The “SWIFT”[107] analysis postulates the failure of a pebble, but the analysis is totally inadequate. By way of illustration of the inadequacy of the “SWIFT” method, the “Risk Assessment” postulates, as a cause of pebble failure in during the operation of the Power and Generation Unit, “Mechanical damage, material fatigue”, as a possible consequence, “Possible increase of waste, possible blockage of the fuel handling system” and proposes as a safeguard “Quality control over fuel manufacturing, filtering systems, waste management system, emergency procedures, design of equip…” This analysis is inadequate because it does not address significant details such as whether it is addressing a scenario of a single pebble failure or multiple simultaneous failures (for example a ‘common mode’ type failure such a manufacturing fault associated with a batch of pebbles, or localised conditions within the reactor, or throughout the reactor or if ‘material fatigue’ is suffered by more than one pebble. The list of possible consequences is inadequate – a detailed

[104] BID, 2C, p9
[105] EIR 2.2.1, p7
[106] EIR, Annexure 11
[107] Annexure 13, **PBMR - EIA Risk Assessment, p4**

description of the possible failure modes would have to lead to a detailed analysis of possible consequences, for example partial blockage of the reactor to gas flow, and the further consequences of such an event. Furthermore, simultaneous failure of different systems do not appear top have been considered at all. This inadequate approach to the analysis of safety risks is contrary to the risk averse approach required by NEMA.

In view of all these factors, it is reckless to site the demonstration plant within 400m of an existing nuclear power plant, in relative close proximity to a public road and to residential areas, and to implicitly assert that the new design is safe enough not to require a containment building. The juxtaposition of two extremely hazardous plants, creates the possibility of 'knock-on' accidents, an accident on one plant triggering a major accident on the adjacent plant. The very novelty of the PBMR design, a factor that is not in dispute, *creates scientific uncertainty with regard to technical performance, economic performance and safety performance.* A more appropriately cautious approach would, for example, have included a secondary containment structure in the design of the demonstration plant, *even if the ultimate objective is to demonstrate, through tests on the demonstration plant, that secondary containment was not necessary.* Yet the applicant, in requesting permission to build a demonstration plant, recognises the implications of this scientific uncertainty only in relation to technical and economic factors, and explicitly (and illogically) rejects the existence of uncertainty in relation to safety (or risk) calculations. This approach is contrary to the letter and spirit of the principles of NEMA.

**5.1.2 The Safety Analysis Report has not been made available for critical public scrutiny. Based on the quotation from the SAR, it is clear that has not responded to or has ignored the extensive in-depth prior analysis of the regulatory problems associated with the licensing of experimental nuclear reactors, specifically in relation to assessing the safety risks the PBMR.**

The SAR has not been made public, so a detailed comment is not possible. The EIR states: "A comprehensive Probalistic Risk Assessment (PRA) demonstrates that the PBMR design meets all regulatory risk criteria."[108] In a Probalistic Risk Assessment, the failure rates used in the analysis, and the structure of the analysis are both based on or strongly dependent on historical data for similar plants and similar or identical equipment. In the case of a novel plant such the PBMR, the important question arises as to how the PRA accounted for failure rates of novel aspects of the design in the risk assessment, or indeed if this factor was considered at all. More fundamentally, uncertainty as to the structure of the analysis of a PRA always remains (that is, uncertainty as to whether or not all possible failure conditions have been considered in the risk calculations), *even for established processes.* In the case of novel processes, this uncertainty is increased to an unknown degree. How was this additional

[108] EIR, 19.5, p212

uncertainty dealt with? The “SWIFT” – Structured What If Technique – method of assessing risks associated with this complex technology is completely inadequate for the purpose because it is premised on prior experience that is not available for a novel process such as the PBMR In addition, the EIR (with Annexures) does not contain basic information needed for the first step in a Risk Assessment procedure, the clear and unambiguous identification of all hazardous substances and intermediates used in the process, a characterisation of these hazards and an inventory of the maximum quantities of these substances present on the proposed site. Whilst some of this information may be gleaned from a careful perusal of the documentation, the SWIFT reports do not contain such data. (The hazard associated with 1 gram of enriched uranium material is clearly very different from that posed by 1 ton of material, hence the importance of inventory data.) In the absence of such information, the EIR does not contain sufficient information for a decision by the regulatory authorities.

It is not clear what the relationship between the SWIFT and PRA reports is (if any), and why have the Applicants have seen fit to make the SWIFT analysis public, but not the PRA?

A study prepared for the Union of Concerned Scientists (July 1990) noted the following issues with safety studies of “Advanced Reactors”, including the PBMR technology[109]: “Similarly, the NRC staff cites seven major sources of uncertainty in risk estimates for the conceptual designs of the advanced reactors proposed by DOE (including MHTGR and PRISM): (a) the limited performance and reliability data for critical systems; (b) the lack of a final design which limits identification of initiating events and dominating accident sequences; (c) unverified analytical tools used to predict plant response; (d) incomplete industry codes and standards for the unique aspects of the designs; (e) the state of the art supporting technology relevant to the designs; (f) extrapolation of research and development results to a full size plant; and **(g)** significantly less design, construction, and operating experience compared with conventional LWRs.” Most if not all of these comments and questions would apply to the PBMR. How were these issues dealt with in the SAR?

### 5.1.3 The EIA Report lacks vital information necessary to enable an assessment of the safety risks of the proposed PBMR

When deciding whether to approve a nuclear power reactor with a novel design, the most critical question that government and the public face is: will this new nuclear reactor be safe? In a presentation to the U.S. Nuclear Regulatory Commission (NRC), Clappison and Mysen of South Africa’s National Nuclear Regulator (NNR) stated:

> “Compliance with the NNR licensing requirements and safety criteria must be demonstrated by way of formalized safety analyses. These safety analyses shall be presented in a Safety Analysis Report (SAR), which shall substantiate the statements,

[109] "Advanced Reactor Study," prepared by MHB Technical Associates, Cambridge, MA. (July 1990)

made in the Safety Case Philosophy and be carried out in an auditable fashion under appropriate QA regime. The SAR is the **principle document** submitted with the various licensing variation applications as part of the staged licensing process. ….”[110]

Underscoring its fundamental importance, the EIA Report for the proposed Pebble-Bed Modular Reactor (PBMR) frequently refers to data in the SAR. For example, Chapter 19 (Safety and Security Impact Assessment) of the EIA Report makes no less than 70 references to data contained in the SAR to substantiate its conclusion that “the safety design of the proposed plant … will ensure the safety of the public.”[111]

Regrettably, the public cannot evaluate the soundness of this conclusion because the actual data contained in the SAR has not been made available to the public as part of this EIA process. For example, data contained in the SAR report that is not part of the EIA report includes:

- the types of nuclear accident scenarios that the PBMR EIA consortium believes are possible;
- the probability that the PBMR EIA consortium assigned to these accident scenarios;
- the extent of radiation releases associated with these accident scenarios; and
- the underlying technical basis for all of the above.

Withholding the SAR report necessarily precludes independent technical review by the public of the fundamental data pertaining to the safety of the proposed PBMR.

#### *5.1.3.1 Under U.S. law, the SAR must be publicly available*[112]

In its report to the NRC, Clapisson and Mysen stated: “In order for the applicant to demonstrate that the reactor will be acceptably safe, it is required that he [sic] demonstrate that the design and operation of the plant … will make use of appropriate internationally recognized design and operational rules.”

In regard to this statement, it is important to note that if an application of this nature were submitted to United States (U.S.) government agencies, presentation to the public of a detailed safety analysis would be required as part of the environmental impact assessment process for the application.

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[110] Clapisson, G.A., Mysen, A. “The first stage of Licensing of PBMR in South Africa and Safety Issues,” page 5.

[111] EIA Report, Section 19.51.

[112] A proper application of South African law in particular s 31 of NEMA would lead to the same result. See paragraph ??? below.

Under Title 10, Part 52 of the U.S. Code of Federal Regulations, an application for a license to establish a new nuclear power reactor:

> "Must contain emergency plans which provide reasonable assurance that adequate protective measures can and will be taken in the event of a radiological emergency at the site."[113]

These emergency plans must:

> "Identify and describe each type of radioactive materials accident for which actions may be needed to prevent or minimize exposure of persons offsite to radiation or radioactive materials. Exposure levels at the site boundary should be treated as the levels potentially affecting persons offsite. Describe the accidents in terms of the process and physical location where they could occur. Describe how the accidents could happen (equipment malfunction, instrument failure, human error, etc.), possible complicating factors, and possible onsite and offsite consequences. Accident descriptions should include non-radioactive hazardous material releases that could impact emergency response efforts. Facilities that can have criticality accidents should evaluate the direct radiation exposure from postulated criticality accidents in addition to the dose from released radioactive materials."[114]

Draft Environmental Impact Statements for new nuclear power reactors must include the detailed content of emergency plans.[115] The full content of Draft Environmental Impact Statements for new nuclear power reactors must be made available to the public.[116] In fact, the U.S. NRC routinely makes available on its website environmental impact analyses of postulated accidents at new and existing nuclear power facilities.[117]

#### *5.1.3.2 The SAR apparently lacks consideration of an accidental fire*

Despite the fact that the PBMR EIA consortium has not made the SAR publicly available, possible safety problems contained in the SAR have found their way to the public domain. In October 2001, G.A. Clapisson of the NNR travelled to the U.S. to attend a workshop about the safety of high-temperature gas-cooled reactors (HTGRs, of which the PBMR is one design). Dr. Dana Powers[118] of the NRC Advisory Committee on Reactor Safeguards

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[113] 10 CFR section 52.79(d).
[114] NRC Regulatory Guide number 3.67 - Standard Format and Content for Emergency Plans for Fuel Cycle and Materials Facilities, Section 2.1, Description of Postulated Accidents.
[115] 10 CFR section 51.71(d).
[116] 10 CFR section 51.74.
[117] Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Calvert Cliffs Nuclear Power Plant (NUREG-1437, Supplement 1), Section 5 - Environmental Impacts of Postulated Accidents, http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1437/supplement1/#_1_56.

attended the workshop and presented a report of his views and those of other experts who attended.[119]

Dr. Powers reported that:

> "G.A. Clapisson provided a review of some of the activities of the South African regulatory authorities with respect to the [PBMR]. They do require that each plant have a probabilistic risk assessment. It appears, however, that this risk assessment does not include accidents initiated by fire."[120]

As discussed below, a graphite fire is a foreseeable accident scenario for the proposed PBMR. The SAR report should include an analysis of this issue.

#### *5.1.3.3 The SAR apparently fails to address lack of an adequate shutdown system*

Dr. Powers also reported that:

> "The South African regulatory authority is suspicious of the column of reflector balls in the center of the core. They are studying it further. They have found that the shutdown system is not diverse. They find that the reactor can become critical as it cools if only one system is deployed. Both systems are required to keep the reactor shutdown. They are asking the designers to re-examine the shutdown system. It is an open question whether a shutdown system outside the core will ever be acceptable."[121]

As discussed below, the PBMR design may be inherently unsafe because it lacks active control measures plant operators could deploy in case of a reactor accident. The SAR report must include an analysis of this issue.

The PBMR EIA consortium must make the SAR available to the public so that independent technical experts may review these potential flaws with the safety analysis of the proposed PBMR. The failure to do this fundamentally undermines the public consultation process. It is unreasonable and regrettable that the South African public must learn about flaws in the safety analysis for the proposed PBMR design through notes, available on the Internet, of a meeting in the United States attended by a South African official.

### 5.1.4 The EIA Report understates the risk of the PBMR design

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[118] Dr. Powers is Senior Scientist at the Nuclear Facilities Safety Department of Sandia National Laboratories in Albuquerque, New Mexico. Dr. Powers is also a senior member of the the U.S. Nuclear Regulatory Commission's Advisory Committee on Reactor Safeguards (ACRS).

[119] U.S. 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., October 10-12, 2001.

[120] Id. at page 9.

[121] Id. at page 9.

#### 5.1.4.1 *The EIA Report fails to discuss features of the PBMR design that render it 'inherently unsafe'*

The EIA Report for the proposed PBMR asserts that "the stated advantages of the PBMR are its radiological safety (inherently safe)."[122] To the contrary, the proposed PBMR is based on a novel nuclear power reactor design that includes features that impair its safety.

##### 5.1.4.1.1 The EIA Report fails to discuss that the PBMR design lacks active controls for modulating radioactive releases from a disrupted core

Unlike conventional pressurized light-water reactors (LWRs), there are few, if any, measures that operators of a PBMR could employ if, for example, a loss-of-coolant accident (LOCA) results in uncontrolled conditions in the reactor core. If a LOCA should occur with the PBMR reactor core, operators can only wait (and pray) that passive controls (such as passive heat conductance) serve to keep conditions under control. This situation is aptly described in Dr. Powers's report:

> "Designers and operators of the current generation of reactors are certain that no matter what happens, their first objective is to get water on the reactor fuel. They want to cool the core and the way to do this is with water. Even if water cannot be supplied in the quantity or the way that leads to prompt quench of the fuel, the water will attenuate the release of radionuclides that pose the hazard to the public. In the long term, water will cool the fuel eventually if it can continue to be supplied. The operators and designers seek this safe haven of a water-cooled core whether the disruptive event has been initiated by stochastic equipment failures that PRAs can calculate, by human errors of omission or commission that PRAs may someday be able to calculate, or by sabotage or terrorist act which analysts despair of ever being able to calculate.
>
> "There is no similar safe haven for the Pebble Bed Modular Reactor. What recourse does the reactor operator have once he has lost high pressure helium coolant? He certainly does not want to replace the helium flow with a flow of air which is the only other abundantly and readily available gaseous coolant. Air will react exothermically with the core and exacerbate the disruption. It will augment rather than attenuate the release of radionuclides. The operator cannot turn to water to cool the core because water will cause the under moderated core to go critical which is certainly not an acceptable turn of events. In the end, some argue that conduction of heat will mitigate the accident, but conduction into soil and concrete is not likely to prevent high temperatures developing in a disrupted core and the extensive release of fission products."[123]

##### 5.1.4.1.2 The EIA Report fails to discuss that nuclear fission in the PBMR core is inherently chaotic and unstable

[122] EIA Report, section 2.2.1.
[123] U.S. 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., October 10-12, 2001, page 4.

Although the fuel spheres tend to assume certain packing alignments (much like oranges align in a fruit crate), these alignments are in flux with each other as the fuel spheres shift position. Furthermore, the uranium pellets in number of fuel spheres never attain exact and reproducible centers of gravity. Since the rate of nuclear fission depends on the exact relative position of enriched uranium fuel elements, this renders fission in the PBMR inherently chaotic and unstable. This situation is best described in Dr. Powers's report:

> "The Pebble Bed Modular Reactor core may be susceptible to neutronic instabilities. The current design for the Pebble Bed Modular Reactor involves a long, low diameter annulus of active fuel. Fuel balls move through this annulus. The fuel density within the annulus varies both spatially and temporally as moving balls achieve various levels of imperfect packing density. The fuel balls do not have centers of gravity coincident with their geometric centers and may, in fact, have multiple, metastable equilibrium positions. Their motions are, then, chaotic and inherently not predictable locally. Wear and damage to the fuel balls during normal operations will make ball motions all the more unpredictable and the temporal and spatial variations in core power greater. Furthermore, the core is "loosely coupled" neutronically. This is all a prescription for core instability akin to the kinds of instability encountered in boiling water reactors. The potential instability is made worse because control rods are not distributed within the local regions of the core, but are arrayed outside the core. …
>
> "The packing density of the fuel balls in the core is not really known. It is likely to vary with time and location in the core. They anticipate a 61% packing density versus the theoretical of 74% for uniformly sized spheres. I am not sure why they expect such a high density. Usually random packing of uniform spheres is less. It is clear that as the balls settle down through the core the packing density will vary. It might well be higher near the bottom than at the top near the point of injection of the recycled balls. There may be a severe control problem because of the varying packing density of the fuel balls.
>
> "Prediction of the motions of the fuel balls must be impossible (not just difficult, impossible). The fuel balls are loaded with coated particle fuel pellets. The loading is not uniform so it is quite unlikely that the center of gravity of a fuel ball will coincide with the geometrical center or even that the displacement of the center of gravity from the geometrical center will be consistent from ball to ball. It may well be that a ball will have multiple, nearly equivalent, metastable points of equilibrium. This will mean that the motions of the balls are chaotic and hence not predictable. I do not know whether the nonuniformity of ball motions and packing will be on sufficiently small scale that average treatments are adequate."[124]

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[124] Id. at page 5.

The EIA Report must discuss how our inability to create a mathematical model for the behavior of the PBMR reactor core contributes to uncertainty in estimates of how the proposed PBMR would perform in reality.

#### 5.1.4.1.3 The EIA Report fails to discuss that the structural integrity of graphite is vulnerable to conditions that occur within the PBMR core

Another inherent flaw in the PBMR design is reliance on the physical integrity of graphite that is subject to high temperatures and bombardment by reactive isotopes. Data gained from our extensive experience with graphite in LWRs, and our limited experience with HTGRs employing fuel spheres, indicate that the physical integrity of graphite may degrade under conditions that occur within the PBMR core. This situation is described by Dr. Powers:

> "The irradiation response of graphite is very dependent on the details of manufacture and no one has been making nuclear grade graphite for a long time. What would be produced now would be different than what had been studied in the past. I am not sure I agree with this position entirely. Some effects are subtle and do depend on microstructural and impurity details. From a regulatory perspective more dramatic effects are usually of more interest and these are not so dependent on the precise details of manufacture. What was surprising is that there seemed to be a poor awareness of the temperature dependence of radiation damage to graphite. Most seemed to be aware of the low temperature radiation damage that afflicted the Windscale reactor (the so-called Wigner energy effect), but did not seem to be aware that there were modes of damage that would not be annealed at the operating temperatures of the Pebble Bed Modular Reactor. Like the Wigner energy, these high temperature radiation damage effects will store energy in the graphite. This energy will be released when the graphite is chemically reacted or heated to a sufficiently high temperature. It is not evident that the stored energy has been taken into account in the analyses of plant responses to accidents."[125]

The EIA Report is replete with references to how graphite contributes to the safety of the proposed PBMR. Therefore, it is fundamentally important that the EIA Report examine conditions that might erode the structural integrity of graphite in the PBMR reactor core.

### *5.1.4.2 The EIA Report understates the temperature the PBMR core could attain*

The EIA Report is replete with assertions that the PBMR reactor core is safe because the core can only get so hot. For example the EIA Report asserts that "when PBMR fuel is without helium cooling, the fuel will not increase to temperatures that can result in significant fission product release."[126]

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[125] U.S. 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., October 10-12, 2001, pages 10-11.
[126] EIA Report, section 2.2.2.

These assertions are inconsistent with data obtained from our limited experience with HTGRs (such as the AVR in Germany that is the primary forerunner to the proposed PBMR) and with our inherent inability to derive mathematical models that describe conditions within the reactor core. This point is explained by Dr. Edwin Lyman,[127] Scientific Director for the Nuclear Control Institute:

> "Previous experience with the AVR test reactor in Germany, a precursor to the PBMR, indicates cause for concern. Experiments measuring the He coolant temperature in the AVR found numerous 'hot spots' in the coolant that exceeded 1280 C, whereas the maximum predicted temperature was only 1150 C. After NRC staff highlighted these findings, Exelon raised the design maximum fuel temperature limit during PBMR normal operation from 1060 C to 1250 C. This is of concern because above 1250 C the SiC layer of the TRISO fuel coating will degrade as a result of attack by palladium isotopes produced during fission. It also calls into question the accuracy of the current generation of computer codes for PBMR core analysis. ….
>
> Thus in order to justify the absence of a leak-tight containment, Exelon needs to demonstrate that the PBMR maximum fuel temperature will not exceed 1600 C during the design-basis depressurization accident, and that more severe accidents that could cause higher fuel temperatures are so improbable that they do not need to be considered. However, given the uncertainties discussed in the previous section --- like a discrepancy between calculated and measured maximum temperatures of at least 130 C --- there are serious grounds for skepticism."[128]

The EIA Report fails to examine how greater-than-predicted temperatures experienced with the PBMR precursor in Germany relate to claims that the PBMR EIA consortium are making about the maximum temperature the proposed PBMR reactor core will attain.

#### 5.1.4.3 *The EIA Report understates the rate of radioisotope release from fuel spheres*

The EIA Report is also replete with assertions that the coating used in the fuel spheres will contain radioactive fission by-products. For example, the EIA Report asserts: "for normal and accident conditions without cooling, the fuel and fission products will be retained within a series of protective boundaries in the pebbles. Equivalent fuel has been tested and significant releases occur only at temperatures exceeding 2000 C."[129]

Again, these assertions are inconsistent with our understanding of the actual and potential behavior of fuel spheres at conditions that may occur within the PBMR reactor core.

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127 For a biography of Dr. Edwin Lyman, see: http://www.nci.org/conf/bio-lyman.htm.
128 Lyman, E. (October 2001) "The Pebble-Bed Modular Reactor (PBMR): Safety Issues," FORUM ON PHYSICS & SOCIETY of The American Physical Society, http://www.aps.org/units/fps/oct01/a6oct01.html.
129 EIA Report, section 2.2.2.

First, the retention by fuel spheres of radioactive fission by-products has not been tested under transient conditions that would occur in the PBMR reactor core. According to Dr. Powers:

> "A tenet of faith is developing that at temperatures below about 1600 C there is no release of fission products from coated particle fuel. This is, of course, not correct. Fission product release from fuel is a function of both time and temperature. It was also noted that all of the test data for fuel had been obtained by heating fuel to a temperature and holding it at that temperature. There had been no tests in which the fuel was put through realistic thermal transients that could thermally shock the silicon carbide cladding on the particle."[130]

Second, there is ample experimental data indicating that PBMR fuel spheres release substantial quantities of potently harmful radioisotopes, including cesium-137, at lower temperatures and under conditions that might occur within the PBMR reactor core. Cesium-137 is the radioisotope principally responsible for excess cancer deaths in the vicinity of the Chernobyl nuclear reactor that caught fire in 1986.[131]

According to Dr. Lyman:

> "There must be assurance that the behavior of the fuel will not be significantly worse than expected if conditions in the core deviate from predictions --- that is, the fuel should 'fail gracefully.' It is on this count that the current TRISO fuel technology is clearly a loser. While past experiments have shown that the SiC layer of TRISO fuel limits the release of highly hazardous radionuclides like Cs-137 to below 0.01% of inventory up to 1600 C, the retention capability is rapidly lost as the temperature continues to increase. At 1800 C, releases of 10% of the Cs-137 inventory have been observed, which is on the order of the release expected during a LWR core-melt accident. Without a leak-tight containment present, the release into the environment would be comparable to the release from the fuel."[132]

In simple terms, with the current design of the proposed PBMR, there would be nothing to prevent a massive release to the environment of cesium-137 if the reactor core were ever to attain temperatures above 1600 C. The coating that surrounds the enriched uranium releases substantial quantities of cesium-137 above this temperature. The inherent complexity of the PBMR design does not allow us to predict with adequate confidence transient maximum temperatures that would occur in the reactor core. Considering the catastrophic health impacts a cesium-137 release would have on the public, the failure of the EIA report to assess these health impacts is a breach of duty to care for public health and safety.

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[130] U.S. 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., October 10-12, 2001, pages 8-9.

[131] NEA Committee on Radiation Protection and Public Health (November 1995) "Chernobyl: Ten Years On Radiological and Health Impact" http://www.nea.fr/html/rp/chernobyl/chernobyl.html.

[132]Lyman, E. (October 2001) "The Pebble-Bed Modular Reactor (PBMR): Safety Issues," FORUM ON PHYSICS & SOCIETY of The American Physical Society, http://www.aps.org/units/fps/oct01/a6oct01.html.

#### 5.1.4.4 *The EIA Report understates the risk of ignition of the core as a result of sudden ingress of air*

As Dr. Lyman noted in his report:

> “Among the largest sources of uncertainty for the PBMR are the potential for and consequences of a graphite fire. The large mass of graphite in the PBMR core must be kept isolated from ingress of air or water. Graphite can oxidize at temperatures above 400 C, and the reaction becomes self-sustaining at 550 C (the maximum operating temperature of the fuel pebbles is 1250 C). Graphite also reacts when exposed to water vapor. These reactions could lead to generation of carbon monoxide and hydrogen, both highly combustible gases.
>
> “If a pipe break were to occur, leading to a depressurization of the primary system, it has been shown that flow stratification through the break can cause air inflow and the potential for graphite ignition. While the PBMR designers claim that the geometry of the primary circuit will inhibit air inflow and hence limit oxidation, this has not yet been conclusively shown.
>
> “The consequences of an extensive graphite fire could be severe, undermining the argument that a conventional containment is not needed. Radiological releases from the Chernobyl accident were prolonged as a result of the burning of graphite, which continued long after other fires were extinguished. Even though the temperature of a graphite fire might not be high enough to severely damage the fuel microspheres, the burning graphite itself would be radioactive as a result of neutron activation of impurities and contamination with ‘tramp’ uranium released from defective microspheres. An even worse consequence would be combustion of carbon monoxide, which could damage and disperse the core while at the same time destroying the reactor building, which is not being designed to withstand high pressure. In contrast, the large-volume concrete containments utilized at most pressurized-water reactors can withstand explosive pressures of about 9 atmospheres.”[133]

As noted above, the EIA Report contains no analysis of the possible environmental impacts should air or water come in contact with the fuel spheres, a very real possibility inherent in the PBMR design.

### 5.1.5 The EIA Report wrongly concludes that containment is not required by ‘Defense-in-Depth’ principles

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[133] Id.

A key to the economic viability of the proposed PBMR is that money will not be spent to construct a pressure resistant, leak-tight containment facility for the reactor core that is required for conventional LWRs. To justify this cost-saving approach, proponents of the proposed PBMR assert that: "a leak tight requirement exists for LWRs as there is a finite chance for core damage with large releases to the containment. The PBMR is designed with the particular purpose of eliminating a core damage scenario."[134]

There are two problems with this approach:

- as discussed above, there is, in fact, a real chance of core damage with large releases inherent with the PBMR design; and
- lack of a containment facility violates the principles of 'defense-in-depth' that are required internationally for nuclear power reactors.

As noted in Dr. Power's report:

> "As currently designed, the Pebble Bed Modular Reactor does not conform with the defense-in-depth regulatory philosophy of the Nuclear Regulatory Commission and could not be certified [in the U.S.]. There is a firm defense-in-depth strategy embedded in the design of power reactors currently operating in the USA. In contrast to what might be argued by those of the rationalist persuasion, this defense-in-depth has nothing to do with compensating for uncertainties of aleatory or epistemic natures. It has to do with the certainty that it is simply impossible to anticipate all the misadventures and combinations of disruptive events that can afflict creation of man. …. There may be solutions to the lack of defense in depth inherent in the current design for the Pebble Bed Modular Reactor. Currently proponents of the design feel the solution is to make it ever less likely that loss of coolant events will occur. This focus on prevention of events flaunts defense-in-depth and everything that has been learned in the past two decades of quantitative risk analysis. A defense-in-depth safety philosophy requires that there be some balance between prevention and mitigation."[135]

Dr. Arjun Makhijani,[136] a nuclear engineer and President of the Institute for Energy and Environmental Research has noted in his analysis of the proposed PBMR:

> "British Nuclear Fuels, owned by the British government, along with other corporate partners, as well as the national South African utility, ESKOM, are in the process of designing a 110 megawatt-electrical PBMR to be built in South Africa... If the reactor is built without a secondary containment, as has been proposed, this could result in a large release of radioactivity. If it is any consolation, the amount of radioactivity in the reactor core per unit of power produced is lower than with other reactor designs, because the fuel pebbles flow continually out of the reactor and are put into storage while new fuel pebbles are fed at the top. This reduces the inventory of short-lived radionuclides, such as xenon-133 and iodine-131 that might be released in the event of a severe accident. It is very questionable that a modular reactor of 110 megawatts could be made economical if a secondary containment were required, as it should be. It is important to remember that the secondary containment was the single feature that prevented the Three-Mile Island

[134] EIA Report, Annexure 10, page 61.
[135] U.S. 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., October 10-12, 2001, page 4.
[136] For a biography of Dr. Makhijani, see: http://www.ieer.org/vitaarj.html.

accident from releasing vast amounts of radioactivity that would have made it more comparable in scale to Chernobyl."[137]

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[137] Makhijani, A. "The Pebble Bed Modular Reactor," http://www.ieer.org/comments/energy/chny-pbr.html.