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ERA EXPIRY DATE

Eskom	**PROJECT EXECUTION RELEASE APPROVAL**	Nuclear Division ERA FORM REV 2 1 August 2010

PROJECT TITLE:

KOEBERG PLANT LIFE EXTENSION (PLEX)

DRA REF NO:	L08016VAR.DRA
BA NAME:	Koeberg Nuclear Power Station
BA CODE:	38
OWNER COST CENTRE:	N/A
ASSET CLASS	

PAIA 37(1)(a). Redacted as it contains personal information of staff no longer in Eskom's employement

REVISION HISTORY		
	VALUE	**DATE**
ORIGINAL		
REVISION 1		
REVI		
REVISION 3		
REVISION 4		

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CURRENT ERA REVISION		
SCOPE	**TIME**	**VALUE**

INVESTMENT CLASSIFICATION	
MANDATORY/STATUTORY	
OPERATIONAL MAINTENANCE	✓
EFFICIENCY IMPROVEMENT	
NEW INFRASTRUCTURE/ CAPACITY	✓

PROJECT CLASS	
CAPITAL	✓
R&E	
CAPITAL AND NON-CAPITAL	

PROJECT DELEGATION	
BUDGETED	✓
UNBUDGETED	
PROJECT DURATION	

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MOTIVATION FOR CAPITAL

This equipment is listed in Accounting Procedure GPC36-226 as a major component of plant that can be classified as Capital

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FINANCIAL PLANNING OF TOTAL PROJECT (DRA AND ERA)

R'M	ITD	2011	2012	2013	2014	2015	2016	Future	Total
Approved Technical Plan									
Approved Budget	N/A	412	PAIA 42(3)(b).Redacted as it contains financial, commercial, scientific or technical information, other than trade secrets, the disclosure of which would be likely to cause harm to the commercial or financial interests of the State or a public body;				N/A	N/A	
ERA Cash Flow Projection									
Variance between Approved Technical Plan and ERA Cash Flow Projection									

REASON FOR VARIANCE FROM:

Approved Technical Plan

The approved technical plan is based upon the assumptions known at the concept phase. The total project expenditure is not within the approved technical plan. However, the bulk of the unapproved portion lies in the 2017-2025 financial years.

Only Phase 1 and Phase 2 of the Plant Life Extension were previously listed on the technical plan and the balance of the funding was not previously on the technical plan due to the scope not being properly formulated at that time and the fact that the implementation strategy was not yet formalised. Since the strategy has recently been endorsed, the updated scope has now been included in this ERA and the consolidated project cashflow has since been added to the 2012-2016 technical plan.

MYPD2 Impact:

The 2011-2015 approved technical plan was used for the compilation of the Multi Year Price Determination 2 (MYPD2) electricity tariff application. The changes to the timing of cash flows are outlined in the table below:

MYPD2 Cash Flow Timing Variance					
R'M	2011	2012	2013	Total	% of PLEX Projection
PLEX ERA Projections					
SGR ERA Projections					
PTR Tank ERA Projections		PAIA 42(3)(b).Redacted as it contains financial, commercial, scientific or technical information, other than trade secrets, the disclosure of which would be likely to cause harm to the commercial or financial interests of the State or a public body;			
Approved Technical Plan					
Variance between Approved Technical Plan and PLEX ERA Cash Flow Projection	355.53	-315.19	-846.47	-806.13	

FINANCIAL PLANNING OF TOTAL PROJECT (CRA, DRA AND ERA) [Continued]

The SGR and PTR Tank replacement ERA projections have been included in the above illustration to show their comparative effect on the PLEX ERA cashflow and the resultant effect on the MYPD2 tariff application.

The current cash flow timing has been aligned with the recent budget quotations and benchmark studies and reflects the expected payment arrangements. The key changes revolve around the payments for the steam generator (SG) forgings, and the earlier commencement of interim payments as determined by the benchmarking exercise. The changes in cash flow timing, which is noted above, results in a variance between the ERA Cash Flow Projections and the Approved Technical Plan. Although the final payment structure will only be confirmed upon contract placement, it is anticipated that a portion of the 2013 expenditure can be delayed,

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Budget

The 2011 approved budget contains a value of I for the PLEX project. The primary reason for the delay in the expenditure projected in the ERA is due to a change in the assumptions relating to the forgings.

his assumption was made during the concept phase when minimal information was available with regards to the evolution of a Steam Generator Replacement (SGR) project. The current strategy is in line with information gathered during the benchmarking evaluation.

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OTHER APPROVALS:

An Environmental Impact Assessment for the extension of plant life for an additional twenty years, logistics around the transport of the SGs to Koeberg on the South African Roads and the use of land to build a storage building for the old SGs and the decontamination facility may be required.

The environmental risk is low with respect to the installation of the SGs and is limited to the storage of the SGs.

National Energy Regulator of South Africa approval will be sought, to approve the additional 20 years of

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operation, during the execution of the project.

National Nuclear Regulator Approval:

	YES	NO
Is National Nuclear Regulator (NNR) approval needed for this intervention?	✓	
If yes, has it been obtained yet?		✓

COMMENTS

The NNR has been informed of the commencement of this project and initial discussions have not raised any threatening issues. Approval will be sought during the project implementation lifecycle and shall follow an agreed licensing framework. This licensing framework will outline the involvement of the NNR at the various project phases.

The key risks related to the approvals required for this project:

- SGR and PTR Tank Replace PAIA 42(3)(b).Redacted as it contains financial, commercial, scientific or technical information, other than trade secrets, the disclosure of which would be likely to cause harm to the commercial or financial interests of the State or a public body; The technical

reasons for non approval are deemed to be low as proven technology is being used, using vendors who are experienced in SG replacements and the fact that many SG replacements have been performed, making SGR a standard modification with known licensing requirements. These factors result in many references being available to the NNR, which will facilitate approval at Koeberg.

- Balance of PLEX Risks

The PLEX EIA is planned to start at the beginning of the execution phase and is expected to require public engagement. It is expected that the EIA will be complete before the end of Phase 1. The licensing risks associated with PLEX lie mainly in the public participation and EIA processes. Onerous Emergency Planning rules which limit development around Koeberg may delay the approval of the PLEX EIA. Should the situation arise where the SGs are replaced and the licensing for PLEX is not approved, then the economic benefits of this project will not be realised.

SCOPE

The scope of this submission includes the short to medium term interventions required to enable the extension of the operating life of Koeberg Nuclear Power Station beyond 40 years. This scope is based on the current material condition of the plant and takes into account the benefit of experience gained from other nuclear utilities which have embarked on similar life extension campaigns. The scope includes all aspects of project management, engineering, procurement, construction, installation and commissioning required for the implementation of the identified initiatives. Where applicable, the scope also includes all activities related to long-term storage of replaced equipment.

The scope of this project has been divided into three phases, viz.:
Phase 1 (Steam Generator Replacement);
Phase 2 (Borated Water Storage Tank Replacement) and
Phase 3 (Unit 2 Reactor Pressure Vessel Head Replacement, Control Rod Drive Mechanism Replacement, Condenser Outer Impact Tube Replacement, Electrical Switchboards and Cabling replacement, and Feedwater Heater replacement).
The phasing of the project is based largely on the certainty of implementation as well as the scope and cost accuracy. Following this approach these high certainty items, which enable PLEX, have been phased in the short term to medium term, with implementation within a ten to fifteen year period.
Items which are required as a consequence of PLEX will be included as additional items in the station Life of Plant Plans. This strategy is supported by the financial modelling which shows that the present value of these costs is negligible.

The illustration below shows the implementation of the relevant phasing:

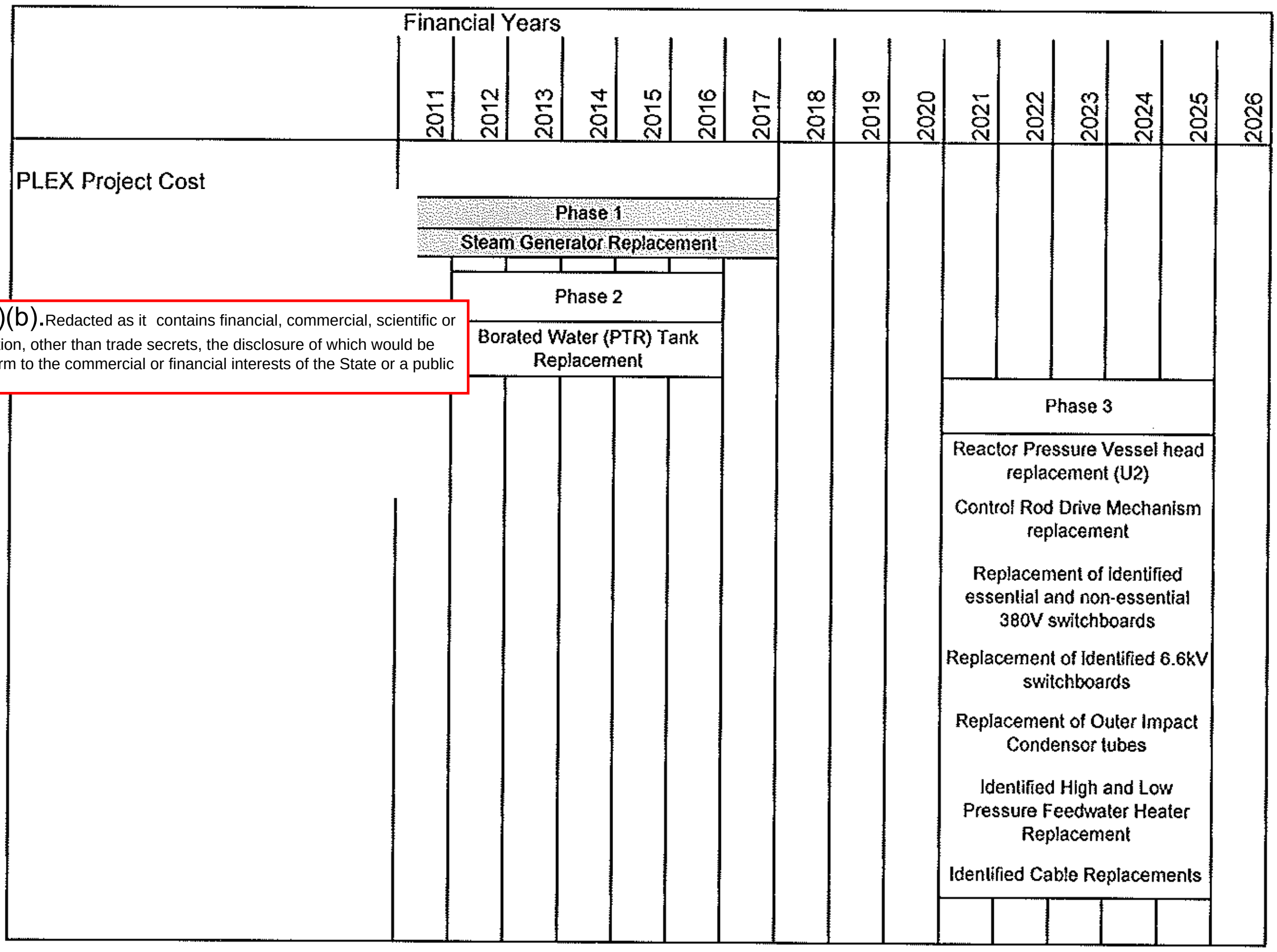

Figure 1: PLEX Project Phasing

Phases 1 and 2 will be run concurrently with PAIA 42(3)(b). Redacted as it contains financial, commercial, scientific or technical information, other than trade secrets, the disclosure of which would be likely to cause harm to the commercial or financial interests of the State or a public body; (planned for 2015-02-16 / 04-11 and 2015-09-14 / [redacted]).

The implementation of Phase 3 planned for Outages 127/227 (planned for 2023-10-01 / 11-24 and 2024-04-28 / 06-21).

Unless specifically stated, all interventions are applicable to Koeberg units 1 and 2.

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EXECUTIVE SUMMARY

An engineering study was conducted by Nuclear Generation Engineering with the support of suitably qualified consultants, into the option of operating Koeberg longer than the currently planned 40 years.

The results of this study show that although it would require capital investment for component replacements, there is currently no known life-limiting component (that is impossible to repair or replace) which would preclude life extension to 60 years.

Conceptual work on Licensing and Environmental Impact Assessment is in progress - these processes present the risk which is hardest to mitigate, since it may involve public participation.

Approval of the associated expenditure of the life extension strategy will be via separate Execution Release Approvals. The Life of Plant Plan will be adjusted for the extended plant life, and the capital investment referred to above would be planned over the remaining life of the station.

Additionally, it has become the norm in the industry to replace steam generators, specifically those with the similar inherent defects and failure modes as those currently installed at Koeberg. The replacement of these components has therefore been instructed by the Nuclear Management Committee.

The steam generators were previously considered to be the life-limiting components due to their replacement cost. Current opinion is that replacement presents an opportunity to both extend the operating life of the units, as well as increase their power output through improved heat transfer capabilities. The change in opinion is predominantly due to the improved returns on investment that operators around the world have realised.

The Long Term Asset Management (LTAM) business case, is based on the above international experience, and has demonstrated the feasibility of the following strategies:

- Koeberg plant life extension from 40 to 60 years,
- Steam Generator Replacement which allows for the opportunity for thermal power uprate,
- Thermal Power Uprate detailed feasibility study to confirm the 10% power uprate.

The abovementioned strategies were approved by the Nuclear Executive Committee on 16 February 2010 and endorsed by EXCO ICAS on 21 April 2010. Board Investment and Finance Committee endorsement was granted on 31 August 2010. The LTAM business case illustrates the integrated and interdependent nature and benefits of the abovementioned projects.

The intent of the Long Term Asset Management strategy is to integrate all known and anticipated technical and economic aspects in order to:

- Ensure that the strategy maintains a high level of nuclear safety coupled with acceptable performance. <u>Note:</u> The safety culture in the nuclear industry requires that steam generators, with inherent defects and failure modes as those currently installed at Koeberg, are replaced rather than managing the increasing risk.

  The replacement of these components has therefore been instructed by the Nuclear Management Committee in 2008.
- Determine the optimum operational life of Koeberg within the Eskom fleet of generators, taking into consideration Eskom's future expansion plans (new technologies).

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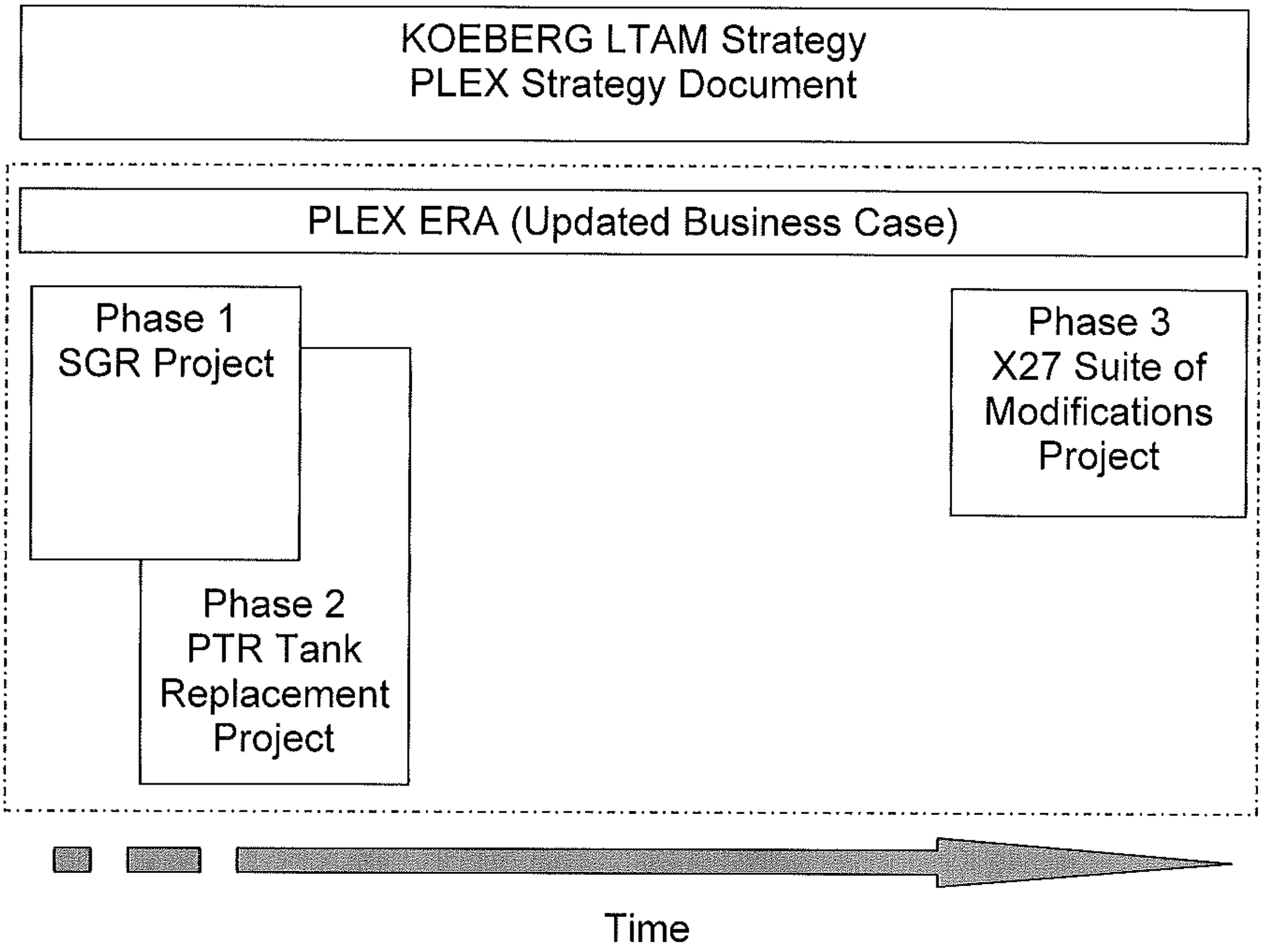
- Confirm a Koeberg asset management strategy to support the operational life.
- Identify opportunities to optimise the generating capacity of the Koeberg units and support these initiatives where economic viability is demonstrated.
- Provide Eskom with a low cost, low carbon generation expansion opportunity.

The illustration below shows the structure of the strategy over time:



NEXCO requested a detailed ERA for the Steam Generator Replacement Project. This ERA was presented to and supported by the Nuclear Investment Committee on the 2010-05-17. This ERA was conditionally supported by EXCO ICAS on 2010-05-31, subject to the approval of the PLEX ERA. The rationale for the conditional support is to allow Eskom to make an informed decision on the Steam Generator Replacement Project, taking into account the overall anticipated costs associated with Plant Life Extension. The LTAM business case demonstrates the economic viability of the Plant Life extension strategy, despite worst case estimates for PLEX initiatives in terms of cost and scope. The intent of this submission is to request approval for those PLEX initiatives which have the highest probability of implementation. The cost accuracy of these items has been improved using current market estimates as well as benchmarking.

This ERA requests approval of the key items required which would enable the life extension strategy. This document does not request funding for the implementation of the Thermal Power Uprate Project.

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The LTAM business case incorporated an economic assessment which analysed the impact of life extension against planned decommissioning. The Levelised Costing Model (LCM) was used and included numerous sensitivity analyses around station end of life scenarios, steam generator replacement dates, capital expenditure amounts and levels of success with thermal power uprate. The economic modelling favours plant life extension to 60 years, together with the concurrent earliest replacement of the SGs and power uprate. The LCM was also used to perform the economic modelling of the options contained in this ERA. The levelised cost of the preferred option of this ERA is R209.91 / MWh, which compares favourably with the levelised costs for Medupi and Kusile and possible future Nuclear new builds. An analysis was also performed on the sensitivity of Capex and shows that an over-expenditure of 66.8% breaks even with the current base case. This proves the robustness of the preferred option. This option thus provides Eskom with an opportunity to both extend the life of Koeberg for 20 years. The project is undertaken to support electricity demand growth and should be evaluated against other capacity options. It furthermore offers this additional capacity at a levelised cost far lower than the costs for both new coal or nuclear.

The development of the business case has yielded sufficient information to demonstrate that a strategic decision could be made to extend the life of the station and that this decision would be economically sound, despite worst-case estimates for associated expenditure.

The project cost is made up of the following four main components:

- The Contract cost of 'his cost includes all the external expenditure for the procurement and installation of the entire PLEX project scope, including the SGR. The cost was made up using budget quotes received from vendors and benchmarked against industry norms. The escalation included in the Contract cost is
- The associated project costs are the Resource costs of The escalation included in the Resource cost is F PAIA 42(3)(b).Redacted as it contains financial, commercial, scientific or technical information, other than trade secrets, the disclosure of which would be likely to cause harm to the commercial or financial interests of the State or a public body;
- The Total Interest of
- The Risk Allowance (. The Risk allowance can be grouped into three main categories:
    - Conventional project risk allowances for inflation, commodities and foreign exchange volatility of
    - Scope and installation related risk allowances of I and
    - Should the SGR project experience delays which threaten the 2015/16 installation, an additional risk allowance of has been included to allow for potential installation during the 2018/19 outages.

Note: A detailed discussion on each of the abovementioned cost elements is contained in the Project Costing Assumptions section.

It is therefore recommended that the interventions identified as enablers of Plant Life Extension be approved.

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JUSTIFICATION FOR EXECUTION RELEASE

Description/functionality of component

Koeberg Nuclear Power Station comprises of two three-loop Pressurised Water Reactor systems designed to produce 2 785 MW (thermal) each. Each unit is designed to give a net output of 921.5 MWe. Koeberg is very similar to the stations of the French CP1 programme, with the reference plant for the nuclear island being Tricastin Unit 1. Commercial operation of Units 1 and 2 commenced in July 1984 and November 1985 respectively.

Problem statement

The licence to operate Koeberg has no specified term and operation of the plant is subject to periodic safety reviews and risk-based assessments. It is accepted, however, that the Koeberg design in conjunction with the initiatives contained in the station Life of Plant Plans, currently supports an operational life of 40 to 50 years.

By 2014, unit 1 will have been in operation for 30 years, with unit 2 reaching the equivalent operational age by 2015. This is typically the point at which nuclear power plant operators purposely evaluate their long-term asset management strategies and, where applicable, either initiate processes for the approval and implementation of justifiable plant life extension initiatives or prepare for decommissioning.

International Approach

Worldwide there is an increasing trend amongst nuclear power plant utilities to opt for life extension, rather than decommissioning, with life extension initiatives currently in progress in the South Korean, Swedish, Soviet, Swiss, United States and French utilities.

The first life extension in the United States was granted in the year 2000, where Calvert Cliffs Nuclear Power Plant was granted a licence to extend the plant's life by 20 years. Since then, most United States utilities have successfully extended their operating licences to 60 years. The Electricité de France Engineering group has performed studies on the Electricité de France fleet of nuclear units and has developed life extension strategies of their own, with the older Electricité de France reactors (Tricastin 1 and Fessenheim1) being assessed as pilots. The view of the French nuclear regulatory authority is that it will provide conditional approval for 60-year operating licenses if the French utility can provide sufficient technical justification. Currently Electricité de France has not identified any technical hurdle that will preclude the motivation from being successfully justified.

In line with these international approaches, Koeberg has commissioned an Long Term Asset Management project with the purpose of facilitating the decision on the optimum plant life of Koeberg units 1 and 2, while taking into account the merits and demerits of current and future project strategies like Steam Generator Replacement, Thermal Power Uprate and Turbine Rotor replacements, etc.

Following an internationally accepted approach (as documented in International Atomic Energy Agency guideline IAEA-TECDOC-1503) a feasibility assessment and project scoping was performed, based on a technical evaluation of systems, structures and components. The assessment was performed by Koeberg, in conjunction with an international consultant (Vattenfall Power Consultants [VPC]) and was focused on plant

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material condition and the requisite refurbishments and replacements for various operating life scenarios.
A decision to strategically align the Koeberg Long Term Asset Management strategy with the Electricité de France plant life extension and ageing management strategy provides further confidence of technical accuracy in scope determination, and also strengthens regulatory confidence and support for the process.
The consolidated results of the aforementioned assessment highlighted the technical challenges (in addition to the current Life of Plant Plans [LOPPs]) which impact the operational lifespan of Koeberg. Whilst interventions requiring significant investment have been identified, the general conclusion is that, when benchmarked against comparable utilities, no prohibitive technical challenges have been identified which would preclude a plant life extension of up to 60 years.

History

In response to various operational threats such as reliability and obsolescence issues, Koeberg has already or is in the process of implementing a number of plant modifications/upgrades. Notable interventions include:

- Replacement of Generator Rotor and future refurbishment programme
- Generator Stator rewind
- Replacement of Low Pressure Turbine Rotors (in progress)
- Generator Transformer replacements
- Control and Instrumentation upgrades (in progress)
- Reactor Pressure Vessel Head replacement (Unit 1)

The above modifications consider the possibility of a 60 year plant life. It is therefore not expected that any significant additional modifications related to these components are required to achieve the 60 year life.

Investment Classification Motivation

The project is classified as 'New Infrastructure/Capacity' and 'Operational Maintenance', and is based on the fact that the components listed in the ERA scope are nearing their end of life and their replacement will enable life extension. The project is undertaken to support electricity demand growth and should be evaluated against other capacity creation options.

Progress / detail of pre-feasibility studies to date

A pre-feasibility study was commissioned in 2007, to assess the feasibility of and scope the project based on a technical assessment of Systems, Structures and Components (SSCs), licensing issues and economic aspects. To ensure that assessments are credible and in-line with internationally accepted standards, Koeberg Nuclear Power Station (KNPS) enlisted the support of an international consultant to assist with the pre-feasibility study.
VPC has performed extensive engineering work in support of a PLEX programme for its plants. In addition, the Swedish utility have successfully completed numerous SG replacements as well as thermal power uprates to levels in line with (and beyond) those targeted by KNPS.

As part of the project pre-feasibility phase, Eskom together with the consultant reviewed the current long-term operating strategy (as contained in the station LOPP and various Nuclear Engineering Position Papers [NEPPs]) and identified deviations to comparable international utilities. VPC made use of their extensive international experience; however, comparisons were made predominantly to utilities within the Swedish Nuclear Fleet. The review also considers those aspects of the KNPS design considered unique or different from that of VPC.

The results of this study were captured in a report - the aim of which is to support a decision for the optimal plant life of the Koeberg units.

The options evaluated were:

- Plant life considering normal maintenance only. Note: This option was only included to highlight any significant issues which challenged the 40 year operating scenario. (It is accepted that the KNPS design in conjunction with the initiatives contained in the station LOPP, currently supports an operational life of 40 to 50 years).
- The interventions required to support a 50 year plant life. This option has been included for reference purposes, since the current KNPS LOPP is based on a 50 year plant life.
- The interventions required to support a 60 year plant life.

Using the guidelines defined in International Atomic Energy Agency guidelines, IAEA TECDOC-1309, cost drivers and categories were identified and described. These were used to compile a cost model which facilitated the cost estimation process. The initiatives identified are those that are complementary to the existing station LOPP. The analysis included labour and material costs, over and above normal running costs and includes all aspects of project implementation (feasibility studies, designs, materials, procurement as well as plant modification).

In line with the defined guidelines, the analysis focused on the following plant areas/components:

- Reactor vessel;
- In-core thimbles;
- Bi-metallic connections;
- Inconel component parts;
- Fuel Channels;
- Steam Generators;
- Large Nuclear Class Heat Exchangers;
- Nuclear Class Piping & Supports;
- Civil Engineering Nuclear Island;
- Turbine;
- Generator;
- Plant Computers (including Instrumentation and Control Components);
- Containment Structure;
- Control Rod Drive System;
- Electric Cables;

- Balance of Plant Piping;
- Pressuriser;
- Reactor Coolant Pumps;
- Nuclear Class Pumps;
- Air coolers;
- Main Condenser;
- Spent Fuel Pool;
- Large Vessels;
- Containment Airlocks;
- Feedwater Heaters;
- Turbine Moisture Separator/Reheater;
- Circulating Pumps;
- Feed Pumps;
- Valves;
- Emergency Diesel Generators and auxiliaries.

In summary, the results of the study show that although it would require capital investment for component replacements, there is currently no known life-limiting component (that is impossible to repair or replace) which would preclude life extension to 60 years.

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- The interventions considered are those identified in the International Atomic Energy Agency document (IAEA-Tecdoc-1309) as cost drivers for power plant life extension (i.e. those plant items which impact the cost of plant life extension). While the scope of the PLEX feasibility study considered all cost drivers, interventions requiring significant capital investment or extended outage durations for implementation were analysed in greater detail. This allowed for grouping of workscope into distinct phases which could be linked to different implementation timeframes. The phases discussed below are regarded to be the critical short-term interventions and forms the subject of this ERA submission. Remaining items have been evaluated and will be included as additions to the station LOPP.

- Phase 1

  Steam Generator Replacement

  The steam generators were previously considered to be the life-limiting components due to their replacement cost. It has become the norm in the industry to replace steam generators, specifically those with the similar inherent defects and failure modes as those currently installed at Koeberg. The replacement of these components has therefore been instructed by the Nuclear Management Committee.

Current opinion is that replacement presents an opportunity to both extend the operating life of the units, as well as increase their power output through improved heat transfer capabilities (since the steam generators transfer heat from the reactor system to the conventional plant).

This project is nearing the completion of the definition phase. The certainty of implementation and definition studies to determine scope and associated cost has allowed for the compilation of an ERA which is currently in the approval process. (EXCO ICAS conditional approval of this ERA was obtained on 31 May 2010).

The contract portion of this phas PAIA 42(3)(b).Redacted as it contains financial, commercial, scientific or technical information, other than trade secrets, the disclosure of which would be likely to cause harm to the commercial or financial interests of the State or a public body;

- Phase 2

  PTR Tank Replacement

  The decision to replace the Refuelling Water Storage Tanks (PTR tanks) has recently been taken by Koeberg, in response to long-standing degradation issues and the proposed life extension. The current degradation management strategies contain risk for long term operation and would preclude life extension of the plant beyond 40 years. This project is currently in the definition phase, and ERA approval is planned for March 2011. Target implementation is planned for The contract portion of this phase is estimated to be

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- Phase 3

  X27 PLEX Workscope

  These interventions have been scheduled during the outages X27 scheduled in 2024/5

  Reactor Pressure Vessel (RPV) Head on unit 2 only and Control Rod Drive Mechanism (CRDM) Replacement on both units

  The discovery of cracked and leaking Inconel 600 RPV head nozzles in Pressurised Water Reactors (PWRs) has raised concerns about the structural integrity of CRDM nozzles throughout the PWR industry. In addition to the nozzle cracks caused by Primary Water Stress Corrosion Cracking (PWSCC), it has been accepted internationally by the nuclear fraternity that the Inconel 182 weld that attaches the nozzles to the Inconel buttering layer, is also affected by PWSCC.

  The originally installed RPV heads of both Koeberg units are affected by this phenomenon, though to different extents. Since the degradation on the unit 1 head was more severe, it was replaced during the refuelling outage in 2008. The state of degradation of the unit 2 head is such that a monitoring regime currently in place assures KNPS of continued safe operation of the plant in the medium term. Replacement of the head is however considered necessary for operation beyond 40 years.

  In addition to RPV Head replacements, international utilities are opting to replace the CRDMs as the existing CRDMs are not expected to last 60 years due to age-related degradation concerns. New CRDM designs are available which minimise the number of pressure-retaining welds which minimises the potential for future leakage. This approach decreases the risk of leakage as well as the cost and radiation dose exposure associated with inspection programmes. The contract portion of this activity is estimated to cost PAIA 42(3)(b). Redacted as it contains financial, commercial, scientific or technical information, other than trade secrets, the disclosure of which would be likely to cause harm to the commercial or financial interests of the State or a public body; The contract portion of this entire phase is estimated to be

Koeberg intends adopting this approach by performing a complete CRDM replacement concurrent with the Unit 2 RPV Head replacement. The approach is driven by the significant saving realised in performing the installation of new CRDMs in the factory, as opposed to a delayed in-situ replacement. Since the Unit 1 RPV Head was installed with the originally installed CRDMs, the new CRDMs will be retrofitted onto the RPV Head installed in 2008. This significantly increases the installation costs due to the complications introduced by removal (cutting of existing CRDMs), welding and non-destructive testing being performed on site, where limited space and radioactive contamination is a challenge. The contract portion of this activity is estimated to cost PAIA 42(3)(b). Redacted as it contains financial, commercial, scientific or technical information, other than trade secrets, the disclosure of which would be likely to cause harm to the commercial or financial interests of the State or a public body;

Condenser Outer Impact Tube Replacement

Analyses performed by Koeberg and operating experience from international utilities suggest that condenser reliability decreases with time, primarily due to droplet impact on the outer tube rows. Consequently, utilities are performing replacement of the most susceptible tubes rows. In line with international practice, the Koeberg Plant Engineering view is that replacement of up to 4000 outer impact titanium tubes for each condenser is required. The contract portion of this activity is estimated to cost PAIA 42(3)(b). Redacted as it contains financial, commercial, scientific or technical information, other than trade secrets, the disclosure of which would be likely to cause harm to the commercial or financial interests of the State or a public body;

Switchboard Replacement

The KNPS high and low voltage electrical switchboards are prone to ageing issues currently being managed by a rigorous periodic maintenance regime. This strategy places an increasing burden on station operating expenditure as well as outage durations. The difficulty in implementing these repair and refurbishment strategies are exacerbated by obsolescence of spare parts and equipment, which could potentially impact on the reliability of the unit. For these reasons, the long term management strategy of these components considers eventual replacement as the only viable solution to achieve a 60 year plant life.

Due to the large volume of components contained within this workscope, the replacement strategy will target an approach which incorporates an identified selection of equipment to be replaced during the X27 implementation outage. Should the need then still exist to perform additional work, the remaining scope being completed during the remaining life of the station. The contract portion of this activity is estimated to cost PAIA 42(3)(b). Redacted as it contains financial, commercial, scientific or technical information, other than trade secrets, the disclosure of which would be likely to cause harm to the commercial or financial interests of the State or a public body;

Cable Replacement

Cable ageing is a known degradation mechanisms affecting nuclear power plants, including Koeberg. Studies currently in progress at Koeberg indicates that whilst it is unlikely that the phenomenon will affect the 40 year plant life, extension to 60 years is not possible without large scale cable replacements - both inside and outside the containment building. In line with the approach followed for the switchboard

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ERA EXPIRY DATE

replacements, the identified scope of cable replacements will be linked to the switchboard replacements. The contract portion of this activity is estimated to cost PAIA 42(3)(b).Redacted as it contains financial, commercial, scientific or technical information, other than trade secrets, the disclosure of which would be likely to cause harm to the commercial or financial interests of the State or a public body;

High Pressure and Low Pressure Feedwater Heater Replacement

The High Pressure Feedwater system consists of four main heat exchanger units. The Low Pressure system contains twelve main heat exchanger units as well as two drains coolers and the associated piping.

Koeberg is currently experiencing degradation of these heaters including damage and wall thinning due to erosion, fretting as well as water hammer. The heaters are subject to a periodic maintenance regime aimed at optimising the useful operational life of the components. Operating experience suggests that this approach potentially results in operational issues, which invariably affects the efficiency and consequent power output of the plant. In response to this some international utilities have already embarked on replacement of these components, with most planning for replacement as part of their life extension plans. The KNPS view is that partial replacement or repair of these components is required to achieve a 60 year life. The repair / replacement strategy will be planned for an identified selection of equipment to be replaced during the X27 implementation outage. Should the need then still exist to perform additional work, the remaining scope will be completed during the remaining life of the station. The contract portion of this activity is estimated to cost PAIA 42(3)(b).Redacted as it contains financial, commercial, scientific or technical information, other than trade secrets, the disclosure of which would be likely to cause harm to the commercial or financial interests of the State or a public body;

Alignment with Electricité de France (EDF)

EDF have stated their intent to embark on a programme to increase the lifespan of its current 900 MW fleet. Regulatory approval processes have been initiated for the proposed life extension of up to 60 years. The approach followed by the French nuclear regulator is to give conditional approval for the 60 year operating licence, provided that EDF supplies sufficient technical justification. The submission will be a continuation of the generic and unit specific justification file albeit more extensive than the current 10-yearly file that documents the reasoning for safe operation for the next 10 years, every 10 years.

KNPS has elected to strategically align its PLEX programme with the EDF programme for the following reasons:

- Design similarities and long-term association

  The design of the Koeberg units is very similar to the stations of the French CP1 programme with the reference plant for the Koeberg nuclear island being Tricastin unit 1.

  For many years, Koeberg has benchmarked and compared with EDF on technical matters. Long-standing alignments and support ranging from emergency planning support, the SG management programme and the more recent safety alignment with EDF has resulted in a mutual understanding of the EDF and Koeberg plant designs.

- To ensure defence-in-depth for the PLEX scope determination

  An accurate and thorough assessment of plant material condition and relevant ageing processes is essential in determining the operational life of plant components, thus providing assurance for continued safety and reliability. In addition, accurate scope determination results in credible input data for investment models, which creates a sound basis for decision-making.

- To streamline the regulatory approval process

The PLEX process involves a large degree of regulatory involvement during all project phases. The responsibility of the plant owner at every stage is to demonstrate that all aspects of PLEX have been diligently identified and addressed, to ensure that the plant can be safely operated for the proposed period.

EDF ageing and PLEX strategy is to extend the life of their units to 60 years which will result in a licensed safety referential which KNPS could follow. The KNPS PLEX follows an internationally proven, accepted approach which essentially conforms to the requirements as set out by the French regulatory body. This provides a reference for the NNR to use which should streamline the regulatory approval process.

Methodology used to Determine Project Estimates

The plant material condition was assessed and the requisite refurbishments and replacements identified for the various plant life options. Following the guidelines defined in IAEA-TECDOC-1309, cost drivers and categories were identified and described.

The current KNPS LOPPs were evaluated and deviations to comparable utilities were identified. The interventions required to address the deviations, together with the associated costs were identified. The costs were based on actual expenditure incurred and include all aspects of project implementation, escalated to 2011 Rands. In cases where limited comparable previous experience was available, a cost estimate was used. It should be PAIA 42(3)(b).Redacted as it contains financial, commercial, scientific or technical information, other than trade secrets, the disclosure of which would be likely to cause harm to the commercial or financial interests of the State or a public body; for those interventions that required either an investme[redacted]tion for implementation. The remaining items were grouped and an estimated cost was determined based on comparable operating experience.

In order to further increase the cost accuracy, the contract costs contained in phases 1, 2 and 3 of this ERA are based on recent budgetary estimates received from vendors for the hardware, engineering and installation. All associated project costs, were estimated by benchmarking against other similar installations.

Strategy for PLEX scope and timing determination

The costing of this submission is made up of the major short-term items considered to be enablers of PLEX. The scope has been grouped into distinct phases, defined primarily by timing of the interventions. The phases are:

Phase 1

Steam Generator Replacement

Project Start: December 2010

Project End: March 2020

Phase 2

PTR Tank Replacement

Project Start: April 2011

Project End: March 2017

Phase 3

RPV Head and CRDM Replacement,

Condenser tubes replacement,

Switchboard Replacement (identified switchboards only)

Cable Replacements (identified cables only),

High Pressure and Low Pressure Feedwater Heaters (identified heaters only)

Project Start: April 2019

Project End: March 2025

The scoping and timing of the above mentioned phases consider:

(a) The certainty that the intervention will materialise.

As previously stated, the total PLEX scope was determined through benchmarking of the current Koeberg asset management strategies against similar international utilities that have performed analyses in support of plant life extension.

A comparison of the current plant material condition with the total PLEX scope was performed. This comparison allowed for identification of the medium term PLEX-enabling scope. Whilst it is impossible to identify with absolute certainty the complete scope of all future PLEX requirements, the approach adopted provides the necessary confidence level that those interventions with the highest probability of implementation are included in the medium term window. Lower probability items have been evaluated and best-estimate provisions for these potential interventions have been made for in the LOPP.

(b) The accuracy of scope/costing.

Cost estimates for hardware identified as potential cost drivers for PLEX were based on:

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- Comparable costs at similar utilities (where possible)
- Indicative price estimates obtained from Original Equipment Manufacturer.

Furthermore, it has to be noted that the timing of the phases shown above are purely illustrative and are subject to change. The subsequent detailed ERAs to release the funds will reflect a more certain time period for the purposes of governance. It is not expected that the timing specified in this document will be updated in future to reflect reality.

PLEX ERA Scope Exclusions

Certain items have been excluded from the scope of this ERA as they have very little or, in some cases, no comparable reference in the international nuclear community. The reason for this is that these modifications have either never been implemented or have low probability of actual implementation. The ability of the vendors to provide cost estimates specific to the Koeberg plant for all PLEX initiatives thus proves challenging, if not impossible.

Items excluded from the scope of this submission based on the considerations discussed in (a) and (b) above are discussed below:

- Replacement of the balance of essential and non-essential 380V and 6.6kV switchboards (and associated cable replacements)

The KNPS low voltage switchboards are prone to ageing issues currently being managed by a rigorous periodic maintenance regime. This strategy places an increasing burden on station operating expenditure as well as outage durations. The difficulty in implementing these repair and refurbishment strategies are exacerbated by obsolescence of spare parts and equipment, which could potentially impact on the reliability of the unit. For these reasons, the long term management strategy of these components considers eventual replacement as the only viable solution to achieve a 60 year plant life. The PLEX ERA project cost therefore makes provision for complete replacement of certain switchboards before the 40 year point. As a consequence the probability of intervention and scope in future years is reduced. This approach considers the fact that the switchboards can be refurbished or subject to partial replacement.

- Balance of Cable Replacements

Cable ageing is a known degradation mechanisms affecting nuclear power plants, including Koeberg. Studies currently in progress at Koeberg indicates that whilst it is unlikely that the phenomenon will affect the 40 year plant life, extension to 60 years is not possible without large scale cable replacements - both inside and outside the containment building. The PLEX ERA project cost therefore makes provision for complete replacement of selected cables (those considered to be the most degraded). As a consequence the probability of intervention in future years is low. The potential scope of future intervention is high due to the fact that refurbishment and partial replacement is not considered possible for this scope.

- Balance of ABP/AHP Heater Replacement

Koeberg is currently experiencing degradation of these heaters including damage and wall thinning due to erosion, fretting as well as water hammer. The heaters are subject to a periodic maintenance regime aimed at optimising the useful operational life of the components. Operating experience suggests that this approach potentially results in operational issues, which invariably affects the efficiency and consequent power output of the plant. In response to this some international utilities have already embarked on replacement of these components, with most planning for replacement as part of their life extension plans The KNPS view is that replacement of these components is required to achieve a 60 year life. The PLEX ERA project cost therefore makes provision for complete replacement of certain feedtrain components before the 40 year point. As a consequence, whilst the probability of intervention for future years remains high, the scope in future years has been reduced. This approach considers the fact that the feedwater heaters can be refurbished or subject to partial replacement.

- Pressuriser Replacement

Due to current degradation concerns on the pressuriser, it is certain that intervention will be required in the future. The original costing obtained from the market is based on a worst case intervention, i.e. complete replacement. While this intervention cannot be ruled out completely (e.g. plants in the US and Sweden have performed pressuriser replacement), it is considered plausible that KNPS could effect a weld repair to ensure continued safe operation for 60 years. The possibility of a heater replacement has been considered in the scope.

- Reactor Bottom Mounted Instrumentation (BMI) Nozzle

Indicative price estimates from ven PAIA 42(3)(b). Redacted as it contains financial, commercial, scientific or technical information, other than trade secrets, the disclosure of which would be likely to cause harm to the commercial or financial interests of the State or a public body; the Bottom Mounted Instrumentation at Koeberg it. The BMI Repair / Replacement would include the following four phases of work scope.

- Development of the weld repair methods and lifetime corrosion analysis
- Development, manufacturing and qualification of the process and tooling
- Qualification of process with the regulatory agency
- Field implementation (site effort)

The experience base for the use of this technology is limited, with only a few plants worldwide having actually implemented the repair. KNPS has already performed some work in determining the state of degradation of its BMIs. Based on these analyses, the certainty of implementation is deemed to be low. It is further assumed the extent of scope is low (in other words, if intervention is required, it is assumed to be only 10% of the penetrations). KNPS may also opt to follow the EDF approach in only developing and licensing a repair method, as a contingency for future possible use.

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- Reactor Pressure Vessel Upper and Lower Internals

Since neither the US nor EDF have identified replacement of the RPV internals as an enabler for a 60 year plant life, the implementation probability is low. However, should intervention be required in the future, it is assumed that the scope will be the 60% of worst case estimate.

- Control and Instrumentation upgrades

Since large scale upgrades of the critical KNPS control and instrumentation are currently in progress, future upgrades are not expected to occur before 2030. Based on the nature of the equipment, the probability and scope of large scale intervention in the future is high.

The additions to the LOPP defined above have all been taken into account into the financial modelling. Each item identified will follow the project life cycle starting at the concept phase. Eventual implementation would be dependant on the outcome of the definition studies, however, for the purposes of modelling, the assumption is made that the activities with the higher probability of occurrence will be scheduled during 2030-2035 and the activities with a lower probability of occurrence will be scheduled during the 2036 to 2041 window.

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Below is a graphical representation of the phasing approach described.

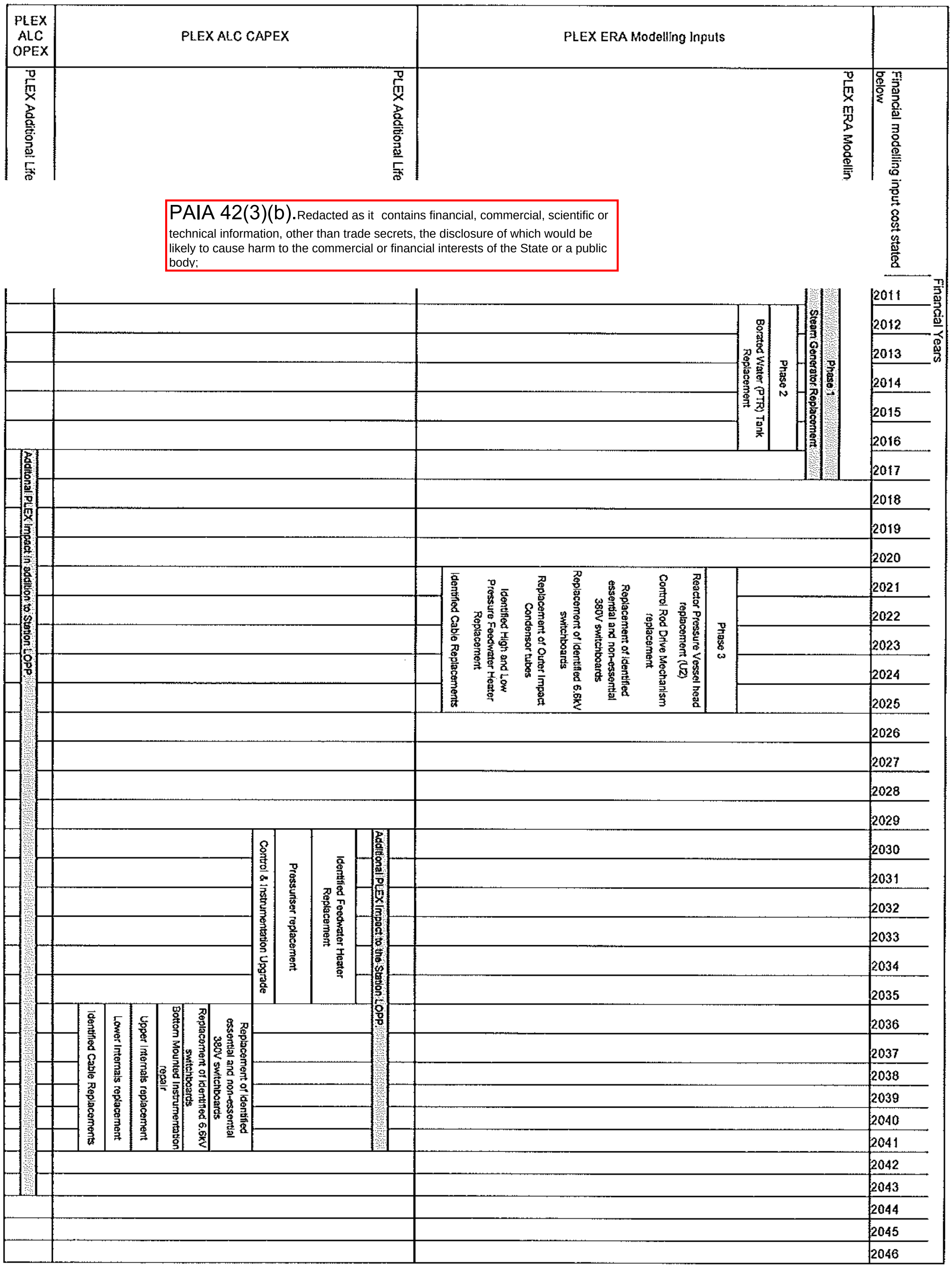

Figure 2: PLEX Strategy

Benefits

The economic benefits of the project are:

- Extending the life of the KNPS units avoids the need for immediate investment in new generating capacity.

- The capital cost of plant life management for PLEX is considerably less than investment in comparable replacement capacity. A preliminary assessment was performed by ISEP, which included the plant life extension to 60 years, together with a 10% thermal power uprate in 2015. This assessment shows that two less open-cycle gas turbines are required in 2019 and the number of coal-fired units to be constructed reduced by two, in the period 2023 to 2028.

- The extended life of KNPS reduces Eskom's reliance on coal power and thereby reduces the impact of future carbon emissions taxes.

- SG replacement gives KNPS the opportunity to increase its power output by up to 10%.

The projects associated with the LTAM strategy also result in additional, non-economic benefits which support ESKOM's strategic objectives. These are discussed below:

- The process of plant optimisation/upgrading and ageing management is a vital requirement in preparing for PLEX. This process involves ongoing research and development efforts to understand and mitigate the effects of ageing mechanisms to justify investment for plant upgrades/management, which invariably improves plant reliability and safety levels. Koeberg continually evaluates potential ageing and life limiting issues via the Koeberg Safety Review Committee. These issues are either incorporated into the LOPP or dispositioned through technical justification. None of these currently alter the conclusions of this document.

- Additional skilled resources will be developed and therefore be available to support the country's future nuclear programme.

- The resultant positive impact on staff morale as a result of extended employment.

- Projects such as SGR and TPU will provide an opportunity to promote government's Competitive Supplier Development Programme.

- The transmission system will benefit in terms of grid stability and the extended availability of low-cost base load in the Western Cape.

Risks

Operation of KNPS for the planned design life of 40 years would instil a culture of managing current plant risks and degradation issues, as opposed to elimination of risk through replacement. Most notable is the management of the risks associated with prolonged operation of the existing SGs for 40 years. There is an inherent risk in operating SGs with known and unknown degradation which could lead to a nuclear accident, significant production loss and create an adverse effect on South Africa's nuclear programme.

Independent Expert opinion

Worldwide, there is an increasing trend amongst nuclear power plant utilities to opt for life extension, rather than decommissioning.

In the United States, 10% of Nuclear Power Plant Licenses will expire in 2010 and an additional 40% by 2015. Consequently, US Nuclear Power Plant utilities have already commenced PLEX programmes, with the first extension granted to Calvert Cliffs Nuclear Power Plant in the year 2000. The utility was granted a licence to extend its life by 20 years. The current operating licence for Calvert Cliffs expires in 2014.

Life extensions are also planned in South Korea, Sweden, Switzerland as well as the Soviet Union, with varied levels of progress.

EDF have stated their intent to embark on a programme to increase the lifespan of its current 900 MW fleet. Regulatory approval processes have been initiated for the proposed life extension of up to 60 years. The approach followed by the French nuclear regulator is to give conditional approval for the 60 year operating licence, provided that EDF supplies sufficient technical justification. The submission will be a continuation of the generic and unit specific justification file that documents the reasoning for safe operation for the next 10 years, every 10 years. Currently Electricité de France has not identified any technical hurdle that will preclude the motivation from being successfully justified.

Recommendation

It is recommended that the Plant Life Extension of KNPS be approved in accordance with the phases outlined in this submission. Approval of this document does not release funding since the initiatives associated with each phase will form the subject of individual investment approval submissions and approval will be sought at the relevant Eskom Holdings Limited approval bodies. This funding application outlines the total impact of PLEX and the financial merits therewith.

REJECTED ALTERNATIVES:

Base Case – Option 1

Description:

The plant life is not extended beyond 40 years. The plant stops operating in 2025/26, in line with the original 40 year operating life of KNPS and the decommissioning of the first Koeberg unit starts in 2025 and the second in 2026.

The SGs are not replaced, but subjected to an intensive maintenance and inspections regime.

No other plant life extension modifications are performed at Koeberg.

Assumptions:

It is assumed that the operation for the balance of the planned 40 years of operation is possible with the current LOPPs. Barring an enhanced SG maintenance strategy, Koeberg requires no major interventions on the remainder of the plant in order to reduce the risk of operation. The assumptions relating to the successful implementation of this option is therefore skewed towards the management of the SG maintenance programme.

Since SG tube degradation is a dynamic phenomenon, inspection scope and technologies are constantly being adapted or refined based on industry feedback from member plants as to the degradation experienced. An effective SG management programme is therefore based on continuous input from plants with similar SGs. As a result of the ongoing replacement of SGs similar to Koeberg's, the operating experience base is rapidly diminishing.

Koeberg therefore faces the challenge of maintaining safe operations with ageing SGs and an ever reducing operating experience base from which to develop inspection programmes. The eventual absence of this operating base will result in an increased probability of an in-service SG tube failure and SG tube rupture event. The increased risk can be mitigated to some extent by adopting an asset management strategy which includes an increased maintenance and inspection programme, coupled with increased engineering resources. In addition to increasing the station operating expenditure, outage durations and radiological dose exposure, such a strategy would be contrary to promoting a prudent nuclear safety culture. This would be unacceptable from a nuclear safety perspective since current inspection technologies are aimed at detecting known degradation mechanisms only. With the decreasing operating experience base brought about by Inconel 600MA replacements, presently unknown (new) degradation mechanisms may not be detected, even with 100% inspections using current inspection techniques.

Operation of the existing SGs beyond 2016 would require increased maintenance in order to 'nurse' the SGs to the end of plant life. These 'nursing' costs will include additional inspections, secondary side deposit management such as chemical cleaning, as well as possible tube repair campaigns such as

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sleeving. This will have a significant impact on operating expenditure as well as radiation dose exposure. In addition, KNPS will need to compensate for the loss of international reference by significantly increasing the SG engineering resource complement, which would further increase the operating costs. It is further assumed that the loss of reference and consequent lack of operating experience results in additional risk, which manifests itself as UCLF (plant shutdowns due to SG integrity issues) and PCLF (increased outage durations due to increased SG maintenance programmes). The engineering assumptions are based on the expectation that each SG tube leak, crack or indication which is a threat to the operation of the plant will require a certain amount of investigation and engineering.

Reasons for rejecting:

Loss of reference:

As detailed above, the KNPS SG Programme is largely dependant on the existence and maintenance of the EDF programme. The KNPS reliance on the EDF programme ranges from complete compliance with the PBMP, to the use of specialised EDF resources for analysis and technical support. While EDF have indicated their intention to maintain the PBMP current until their last Inconel 600MA SG is replaced in 2016, it is unlikely that their programme will be kept current beyond this date. Hence, operating the SGs beyond 2016 precludes continued alignment with the EDF SG management programme. For KNPS, SG replacement beyond 2016 therefore implies:

- Reduced bases for regulator-approved ISI scope for SGs.
- Loss of dedicated technical support and analyses (3rd party review) for routine and non-routine SG inspections.
- Reduced exposure to relevant operating experience events.
- The associated risk of operating SGs with known (and unknown) degradation. Risks stemming from degradation mechanisms currently not analysed in the PBMP are increasing in frequency of occurrence. These are typically age-related issues such as Tube Support Plate clogging and partition plate cracking. Early detection of these forms of degradation is essential from both a nuclear safety and plant availability perspective. In this respect, Koeberg is currently completely dependant upon the large operating experience base of similar SGs in the world, especially EDF.

Peer/Regulatory Pressure

The international SG management trend indicates that utilities are replacing 600MA SGs in order to completely eliminate, as opposed to managing SG failure risk. Consequently, the number of Inconel 600MA SGs are declining to the extent that – should Koeberg elect to replace SGs at the end of the 40 year life – these SGs would be the oldest and only remaining Inconel 600MA SGs in the world. Extended operation of the Koeberg Inconel 600MA SGs will, as a consequence, result in increased risk and therefore, regulatory pressure in the future. This could adversely affect future WANO / INPO perceptions regarding the safety of these SGs.

The SG management programme has recently come under intense scrutiny which resulted in a WANO AFI due to deviations from accepted international SG management strategies. It is envisaged that KNPS will continue facing the increasingly challenging task of justifying its position to operate the last remaining Inconel 600MA SGs in the world.

<u>Steam Generator Tube Rupture (SGTR)</u>

The risk for a potential SGTR event increases with time. This unquantifiable risk exposes Koeberg to many catastrophic consequences as the replacement dates of the last Inconel 600 SGs in the international fleet approaches.

<u>Economics and Loss of Opportunities</u>

When considering a 60 year time frame in accordance with the LTAM business case, it is not economically feasible to pursue this option. This is due to two main reasons. Firstly, the replacement energy would need to be produced at a far higher marginal cost for 20 years compared to the preferred option. Secondly, Eskom will not be able to exploit the opportunities outlined below.

The SGR project is a key enabler of PLEX and TPU. The LTAM business case incorporates the integrated benefits of these three projects in one analysis. The detailed economic results are discussed in detail in the LTAM business case.

The most noteworthy consideration in the LTAM business case is that the SGR provides the capability to extend Koeberg's operations by an additional 20 years. The benefit is the additional 1800 MW capacity produced with mostly the existing infrastructure. Furthermore, the effect of TPU is that an additional 10% thermal power is available at the same date of the SGR until the end of plant life in 2045/46. If an SGR is not implemented, then technically it is not possible to perform the PLEX and TPU projects and thereby both extend the life of Koeberg by 20 years and increase its power output. This in turn increases Eskom's exposure to potential increased carbon emissions tax as more fossil fuel will be used to generate electricity.

<u>Option 3</u>

Description:

Implement the PLEX project scope, with the SGs replaced in 2018/19; stop operating in 2045/46.

Assumptions:

This option is identical to the preferred option, except for the following:

- it entails a delayed implementation

- additional nursing costs up until 2017/18, in the form of an increased inspection programme

Reasons for rejecting:

The later SG replacement date when compared to the 2015/16 replacement exposes Eskom to a risk of UCLF. A further concern is that the units will be subjected to extended operation and therefore at an increased risk of SG tube cracks and SGTR.

This option is marginally more costly than the preferred option mainly due to the assumptions of increased project costs, additional PCLF and nursing costs.

This option is technically feasible and the prospect of a later delivery of the SGs may in fact force the implementation of this option. However, despite its technical economical feasibility, it is preferred to install at the earliest possible opportunity for the reasons outlined above.

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ASSUMPTIONS

	Base case	Preferred Option	Rejected Alternative
OPTIONS	**1. Maintain, do not replace SGs; stop operating in 2025/26**	**2. PLEX Scope, with SGs replaced in 2015/16; stop operating in 2045/46**	**3. PLEX Scope, with SGs replaced in 2018/19; stop operating in 2045/46**

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Refer Modelling Input Assumptions (Page 56/57) for a detailed breakdown of these costs.

DESCRIPTION OF ECONOMIC ASSUMPTIONS:

OPTION 1: Do Nothing. Stop operating after 2025/26

The expected plant life is 40 years. The end of life of units 1 and 2 is assumed to be during the 2025/26 financial year. No change to the Sent Out Capacity of the units is anticipated and it is assumed that 1800 MW is generated by KNPS until 2025; thereafter only unit 2 will operate for the last financial year (i.e. 900 MW in 2026). The system marginal cost of energy is used to calculate the cost of the energy displaced (285 300 GWh) as result of shutting down KNPS in 2025/26.

The Capex and Opex Additional Lifecycle cost associated with the base case include the current LOPP costs forecast for the remainder of the 40 year life of the station. This cost has been estimated by the Koeberg engineering division and is related to the projects which are deemed to be necessary to ensure continued operation until 2025/26.

The Capex LOPP equates to PAIA 42(3)(b).Redacted as it contains financial, commercial, scientific or technical information, other than trade secrets, the disclosure of which would be likely to cause harm to the commercial or financial interests of the State or a public body; xpenditure for this option.

The Opex Life Cycle costs equates to spread over the remaining life of the plant. This Opex Life Cycle cost equals the Opex LOPP of I plus the SG nursing costs of It is assumed that additional maintenance and inspection is required to 'nurse' the SGs to the end of plant life. The nature of these 'nursing' costs has been described above and amount to
For a breakdown of these life cycle costs please refer to Annexure A.

The UCLF impact calculation is based on the assumption that the SGs will deteriorate with time and will result in an average unplanned loss of 14 days per unit per annum starting in 2017/18 until the end of life of plant. This assumption is very conservative as one event of this nature could be catastrophic and could lead to a significant amount of UCLF prior to recovery (if at all possible). These assumptions are complicated by the fact that the loss of reference to EDF SG engineering does not allow for any worldwide comparisons and assumes that Koeberg engineering alone will be sufficient to motivate the regulator to restart the affected unit. This gives rise to a total loss of 4 838 GWh. The calculation methodology of the UCLF follows below:

- Four separate incidents of tube leaks have been assumed to occur prior to 2025/26, and result in OTS-enforced shutdowns due to unacceptable primary to secondary leakage. This will result in the unloading of the core and the plugging of the affected tube/s. The estimated time period to achieve this, based on Koeberg experience, is 35 days of UCLF. It is thus assumed that it takes a minimum of 35 days to repair each of these tube leak incidents.
- Furthermore, additional unforeseen work of duration of 7 days UCLF per outage occurs in the form of outage slip from 2018 through to 2025 due to unknown degradations that escalate in line with the age of the SGs.

The total number of lost time associated with the above equals 224 days. As the exact timing of these failures cannot be predicted, an equal probability of it occurring between 2017/18 and 2024/25 has been assumed. This implies a UCLF average of 28 days per annum for both units (224/8 = 28 days).

The PCLF impact calculation is based on an estimated delay of 20 days to each refuelling outage as a result of additional maintenance required to 'nurse' the SGs until the end of plant life. This additional outage duration is linked to international operating experience related to the increased inspection and management regime required to extend the life of SGs. This gives rise to a total loss of 6 048 GWh.
The calculation methodology of the PCLF is as follows:

- It is assumed that two chemical cleaning campaigns will be required to ensure the integrity of the SGs. Each campaign is expected to require 62 days in addition to a 55 day outage duration.
- It is also assumed that two campaigns of tube sleeving are required to re-introduce tube plugging margin. Each campaign is expected to require 50 days in addition to a 55 day outage duration.
- An additional 4 interventions of an increased inspection campaign will be required of a minimum of 14

days each.

There are 14 remaining outages between 2016 and 2026 according to Revision 61 of the Koeberg 10 Year Production Plan. The total cumulative effect of the above assumptions equal 280 days. These 280 days have been spread over the remaining outages between 2015/16 and 2025/26. This implies a PCLF average of 20 days per outage per unit (280/14 = 20 days).

OPTION 2: Implement the PLEX Scope, with SG replacement at 2015/16. Stop operating after 2045/46

The Capex project cost (R12 557.16 M) consists of the SGR project cost and the PLEX project cost.

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- The PLEX other project cost is based on the scope of this document excluding the SGR. The cost includes all the significant project costs which will be required to be implemented in the foreseeable future in order to extend the life of the plant for an additional 20 years i.e. a total operational life of 60 years. This expenditure is planned for execution over the period starting in 2012 until the final intervention in 2025 and totals

The Capex a PAIA 42(3)(b). Redacted as it contains financial, commercial, scientific or technical information, other than trade secrets, the disclosure of which would be likely to cause harm to the commercial or financial interests of the State or a public body; ne Capex LOPP and the additional life cycle expenditure anticipated for the extension of the life from 2025/26 until 2045/46.

The Capex LOPP is the cost up to the planned 40 year plant life and the additional 20 years of operation which has been extrapolated according to the current profile. This element totals

The additional life cycle cost for PLEX (ALC–PLEX) incorporates all the lesser modifications, upgrades and replacements necessary to extend the life of the plant to 60 years. The cost of these interventions total and the expenditure ranges from 2030 to 2041. The make up of this cost is based on the assumptions related to probability of implementation and the most likely workscope required to be implemented during the latter stages of the station life. The probability of occurrence used in this model was determined based on the number of times these activities were required in other worldwide pressurised water reactor power stations and the current plant condition at KNPS. The cost used as an input to this model was determined from budget quotations received from suppliers.

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The input criteria used to develop the PLEX additional life cycle cost is shown below:

Item	Probability of intervention	Best estimate Extent of scope	Original cost (In R'000)	Modified cost (In R'000)	Early Replacement (2030 - 2035)	Late Replacement (2036 - 2041)
Replacement of the balance of essential and non-essential 380V switchboards	37%	18%				
Replacement of the balance of 6.6kV switchboards	15%	60%				
Balance of ABP/AHP Heater Replacement	95%	40%				
Balance of Cable Replacements	20%	75%				
Pressuriser replacement	90%	20%				
BMI repair	30%	10%				
Upper Internals replacement	25%	60%				
Lower Internals replacement	25%	60%				
C&I Upgrade	100%	90%				
Totals						

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The Opex additional life cycle cost (R15 458.26 M) consists of the Opex LOPP (up to 60 year operation), the 'Nursing' cost and the Opex ALC-PLEX.

The Opex LOPP is the cost for the additional 20 years of operation has been extrapolated according to the current profile. This element to PAIA 42(3)(b).Redacted as it contains financial, commercial, scientific or technical information, other than trade secrets, the disclosure of which would be likely to cause harm to the commercial or financial interests of the State or a public body;

The 'Nursing' cost is minimal in this scenario as the SG replacement date is at its earliest. The total expenditure is for the 2011-2013 period.

The additional life cycle cost for PLEX (ALC–PLEX) has been calculated during the pre-feasibility studies and incorporates all the lesser modifications, studies, upgrades and replacements necessary to extend the life of the plant to 60 years. The cost of these interventions total and the expenditure ranges from 2017 to 2043.

The additional 20 years of operation allow the benefit of an instantaneous 900 MWe per unit to be attributed to this option until 2045/46.

The effect of reversing the Operation at Reduced Temperature results in an additional instantaneous 18 MWe per unit post SG replacement.

The total impact for this option is an additional 8 492 GWh.

No UCLF or PCLF impact is assumed in this option as the SGR is performed prior to the loss of reference.

OPTION 3: Implement the PLEX Scope, with SG replacement at 2018/19. Stop operating after 2045/46

The Capex project cost (R13 122.80 M) consists of the SGR project cost and the PLEX other project cost.

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- [redacted] excluding interest, escalation and cost of cover is estimated at [redacted] is higher than that of option 2 primarily as a result of the effect of [redacted] years with higher exchange rates and the effect of the extended manufacturing programme requiring the same resource profile over a longer period and thereby increasing the project cost.
- The PLEX other project cost is based on the scope of this document excluding the SGR. The cost includes all the significant project costs which will be required to be implemented in the foreseeable future in order to extend the life of the plant for an additional 20 years i.e. a total operational life of 60 years. This expenditure is planned for execution over the period starting in 2012 until the final intervention in 2025 and totals [redacted]

The Capex additional lifecycle costs [redacted] consist of the Capex LOPP and the additional life cycle expenditure anticipated for the extension of the life from 2025/26 until 2045/46.

The Capex LOPP is the cost up to the planned 40 year plant life and the additional 20 years of operation which has been extrapolated according to the current profile. This element totals [redacted]

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The additional life cycle cost for PLEX (ALC–PLEX) incorporates all the lesser modifications, upgrades and replacements necessary to extend the life of the plant to 60 years. The cost of these interventions tota [redacted] and the expenditure ranges from 2030 to 2041. The make up of this cost is based on the assumptions related to probability of implementation and the most likely workscope required to be implemented during the latter stages of the station life. The cost used as an input to this model was determined from budget quotations received from suppliers. The profile of this expenditure is shown in the discussion on option 2, above.

The Opex additional life cycle cost (R15 890.87 M) consists of the Opex LOPP (up to 60 year operation), the 'Nursing' cost and the Opex ALC-PLEX.

The Opex LOPP is the cost for the additional 20 years of operation has been extrapolated according to the current profile. This element totals

The 'Nursing' cost is more than that of option 2 as the SG replacement date is 3 years later. The total expenditure is or PAIA 42(3)(b). Redacted as it contains financial, commercial, scientific or technical information, other than trade secrets, the disclosure of which would be likely to cause harm to the commercial or financial interests of the State or a public body;

The additional life cycle cost for PLEX (ALC–PLEX) has been calculated during the pre-feasibility engineering and incorporates all the lesser modifications, upgrades and replacements necessary to extend the life of the plant to 60 years. The cost of these interventions total and the expenditure ranges from 2017 to 2043.

The additional 20 years of operation allow the benefit of an instantaneous 900 MWe per unit to be attributed to this option until 2045/46.

The effect of reversing the Operation at Reduced Temperature results in an additional instantaneous 18 MWe per unit post SG replacement.

The total impact for this option is an additional 7 665 GWh.

It is assumed that no UCLF is incurred in this option. The PCLF risk is limited to 2 outages as the EDF SG reference will be available until 2016. The exposure is therefore limited to the period between 2015/16 and the replacement date. This gives rise to a total loss of 864 GWh (5,48% PCLF), which is based on an additional 20 days in one outage.

RESULTS:

Investment Classification	Operational Maintenance

Nature of Project:

Sustainment	
Betterment	✓

LCM Results – *60 year station life*

The LCM results for the entire PLEX project is shown below, and reflects the additional 20 years of availability benefits as a result of the SGR. The 60 year analysis includes both the costs and benefits arising from a plant life extension.

PLEX Levelised Costing Model (LCM) Results			
Scenario Description	**1. Maintain, do not replace SGs; stop operating in 2025/26 (40y)**	**2. PLEX Scope with SGR in 2015/16; stop operating in 2045/46 (60y)**	**3. PLEX Scope with SGR in 2018/19; stop operating in 2045/46 (60y)**

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Commentary on results:

The economic evaluation conclusions are based on the present value levelised costing comparison between the options presented.

The LCM model used is the one in effect on 2010-08-26 and the Eskom Economic Evaluation Parameters are as specified in document 323-09 Rev 0.

The preferred option (2) is the option with the lowest cost per MWh and is 24% more cost effective than the base case. This is due to the significant operational benefits provided by plant life extension through a steam generator replacement and the other PLEX initiatives. The results also support an intuitive perception that the sooner a project of this nature is implemented, the greater its impact, both in terms of extended availability and additional MW sent out.

The option of implementing the PLEX interventions, including Steam Generator Replacement in 2015/16 is therefore selected as the preferred option.

SENSITIVITY ANALYSIS AND RISKS:

Scenario Description	Preferred Option	Sensitivity 1 Option 2 with Capex increased by 25%	Sensitivity 2 Option2 with Capex increased with 66.8%

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COMMENTARY ON RESULTS:

A sensitivity analysis was performed based on the project Capex variable. Two scenarios are notable:

- Sensitivity 1 – The project Capex is increased by 25%.

  The result of this sensitivity analysis shows that by increasing the project Capex of scenario 2 by 25%, the breakeven point is reached with scenario 3.
- Sensitivity 2 – The project Capex is increased by 66.8%

  The result of this sensitivity analysis shows that by increasing the project Capex of scenario 2 by 66.8%, the breakeven point is reached with scenario 1, the base case.

The conclusion of this analysis is that the economic merits of the preferred option are proven, as the effect of changes on the Capex variable shows that scenario 2 is reasonably well protected from fluctuations in Capex value.

TECHNICAL PLANT RISKS:

A detailed business impact assessment has been performed and the mitigation of the risks is incorporated in the project planning. This has been presented to the Koeberg and Nuclear Generation Engineering teams and business forums and the detail of the risk assessment is contained in the LTAM business case.

PROJECT RISKS/INVESTMENT RISKS:

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The Risk Allowance has been calculated using the guidance of the ʿThe local inflation, commodity volatility and the volatility of the rate of exchange variances have been mitigated as guided by the practice note for each phase of the project.

Other specific risks have been mitigated by the inclusion of a general risk allowances to provide for changes in budget quotations, expediting the schedule, and allowances for unknown scope. The value of the risk allowances are based on a quantitative analysis of similar projects and these will be defined in detail in the ERAs required to release the funds for each of the PLEX phases.

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Specific risk allowances are made for :

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PROGRAMME:

Start date(s)	**2010-12-03**

UNIT	**Scheduled outage dates**	**Non-scheduled outage dates**	**Transfer into CO date**	**Value into CO**
Unit 1	121	N/A	2015-04-11	
Unit 2	221	N/A	2015-11-07	
Unit 1	122	N/A	2016-10-16	
Unit 2	222	N/A	2017-05-14	
Unit 1	123	N/A	2018-04-08	PAIA 42(3)(b). Redacted as it contains financial, commercial, scientific or technical information, other than trade secrets, the disclosure of which would be likely to cause harm to the commercial or financial interests of the State or a public body;
Unit 2	223	N/A	2018-11-04	
Unit 1	124	N/A	2019-10-26	
Unit 2	224	N/A	2020-05-15	N/A
Unit 1	125	N/A	2020-12-26	
Unit 2	225	N/A	2021-07-29	
Unit 1	126	N/A	2022-06-04	
Unit 2	226	N/A	2022-12-24	
Unit 1	127	N/A	2023-11-24	
Unit 2	227	N/A	2024-06-21	

Note that the value of one installation is assumed here to be 50% of the project cost and this value will be transferred to Commercial Operation as the installation occurs

One installation will consist of 3 SGs installed in one unit during the same outag

This programme is based on I of the Koeberg 10 Year Production Plan.

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DRA VALUE:	
ERA VALUE:	
ERA EXPIRY DATE	

End date (s)	**2024-06-21**

Proposed FRA date	**2025-03-31**

Note that the end date and the Finalisation Release Approval (FRA) date shall be no later than that stated above, however in the event of an earlier implementation; the end date is estimated to be at the completion of the second installation and the FRA date will be 9 months later than the end date.

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ERA EXPIRY DATE

PROJECT COSTING ASSUMPTIONS:

Base date:	**2010-07-27**
Contract Date:	**2011-04-20**
Basis of estimate	
Budget quote	✓
Similar scope of work	✓
Quantity surveyor	
Comments: Detailed discussion of the costing assumptions is contained in the next project cost breakdown section.	

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Confidence level of costing	90%	SGR - Based on 2007 budget quote and benchmarking studies, without stimulating the market. PLEX Phase 2 and 3 – based on budget quotations from vendors. Confidence levels of each Phase ERA will be improved closer to the implementation date.

	2011	2012	2013	2014	2015	Future	Source

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Foreign Currency Conversions

	2011	2012	2013	2014	2015	Future	Source
Local/Foreign Split %							
Local						N/A	ERA Projections
Foreign						N/A	
Currency							
USD	N/A	N/A	N/A	N/A	N/A	N/A	
EUR							

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PROJECT COST BREAKDOWN

The PLEX project is estimated using budget quotations and market indications received during July 2010. These market estimates have been interrogated and supplemented with a multitude of inputs using information retrieved from the experience of other utilities.

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The project has been broken down into four key phases, based on the intervention timing requirements specified by the client, namely:

1. The Steam Generator Replacement Project
2. The PTR Tank Replacement Project
3. The X27 Suite of Modifications

The total project cost projection shown above incorporates all of the PLEX project phases, and the following discussion of the total project breakdown will illustrate the costing methodologies and assumptions applied to each of these phases.

The next section will present each of the subtotals for each phase of the:

- Contract,
- Resource,
- Cost of Cover,
- Interest, and
- Risk Allowance

The narrative following the tables, shall provide a high level discussion of the major cost estimations for each section.

General costing assumptions:

The detailed costing model, which matches the project schedule, will not be presented in this document and for the sake of succinctness; the project cost make up will be discussed at a high level.
All foreign costs are calculated using the Economic Evaluation Parameters (EEP) and are based on the relevant exchange rates applicable to the year of expenditure. For simplicity sake, all external contract costs are assumed to be in Euro.

The first phase of the PLEX project is the SGR project and even though this financial application incorporates the costing of the SGR project, a separate, more detailed financial application will be submitted in parallel to this application.

The Definition Phase is currently in progress and the technical specification is currently being compiled along with certain other identified feasibility related work. The reasons for the urgency of this project have been discussed earlier in this document and therefore this project is being fast tracked in order to meet the long delivery lead times of the SG manufacture (36 month manufacture period).

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The SGR project has been broken down into three key phases, namely:

1. Manufacture and Delivery of the SGs,
2. Safety Analysis (Plant / SG interface), and
3. Installation of the SGs.

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Phase 2: PTR Tank Replacement

The cost estimation exercise for Phase 2 to 3 of the PLEX project has been performed using a similar approach for each phase. The contract cost was developed using the budget quotations received in July 2010 from the applicable vendors. The budget quotation was interrogated and a technical evaluation was performed to determine the portions of scope included and excluded. The scope excluded was conservatively estimated using the experience of the project team and where possible, recent similar work-scope costing.

Since the timing of the cashflow is not yet determined, a cost profile was developed and applied to the contract costs of the projects. This profile is shown below as a cumulative expenditure graph.

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The same principle has been applied to the remainder of the PLEX project scope, listed below:

Phase 3 : X27 Suite of Modifications

RPV Head and CRDM Replacement,

Condenser outer impact tube replacement,

Switchboard Replacement (Identified workscope)

Cable Replacements (Identified workscope),

High Pressure and Low Pressure Feedwater Heaters (Identified workscope)

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ERA EXPIRY DATE	

RESOURCES MANAGEMENT & ASSUMPTIONS:

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COST OF COVER

The cost of cover shown above has been calculated according to the expenditure profile which matches the schedule. All parameters used in the calculation have been extracted from the EEP and the Treasury website.

INTEREST DURING CONSTRUCTION

The interest allowances shown above have been calculated according to the expenditure profile and the interest rates in the EEP.

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RISK ALLOWANCE

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REV:

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Note: The shaded cells are not used in the calculations and are shown for illustration of the foreign component.

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ERA EXPIRY DATE

ASSOCIATED PROJECT(S)/SCHEMES:

1. Long Term Asset Management Strategy

2. Steam Generator Replacement Project

3. Thermal Power Uprating Project

STATUS OF THE ABOVE PROJECTS/SCHEMES:

1. A LTAM business case on the strategy for this project has been approved by the Nuclear Executive Committee. This LTAM business case will be presented to the Eskom Board of Directors Investment Finance Committee for endorsement.

2. This project is in the definition phase and the ERA has been successfully presented to the NIC and the EXCO ICAS.

3. The Thermal Power Uprating project has an approved DRA and the project is in the definition phase.

SHE: SAFETY. HEALTH AND ENVIRONMENTAL CONSIDERATIONS:

The SHE considerations have been investigated during the definition phase of the project and this analysis has highlighted the following:

- the need to perform an Environmental Impact Assessment for the logistics around the operation of the Koeberg NPS for an additional 20 years,
- the transport of the SGs to Koeberg on the South African Roads and the use of land to build a storage building for the old SGs and the decontamination facility.

The environmental risk is low with respect to the installation of the SGs and is limited to the storage of the SGs.

Detailed risk assessments of the manufacture and installation phases of the project will be undertaken by the contractor and will be incorporated into the implementation plans.

All attempts will be made to minimise the impact of this project with regards to the SHE considerations.

REV:

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INCOME TAX IMPLICATION:

Section 12C (New and Unused Machinery)	**Yes**
S11 (bA) (Pre-production Interest)	**Yes**
S11 (a) (General Deduction Formula – R & E)	**Yes**
Section 11(e) (General Deduction Formula – Capital)	**No**

Income Tax Breakdown:

External Services (Turnkey Contracts)
External Services (Rates Based Contractors)
Internal Costs
Other Costs (Insurance)
Sub-total
IDC
Overheads
Forward Premium
Risk Allowance
Total ERA Value

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Alternative tax treatment:

None

PFMA IMPLICATIONS:

None

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NUCLEAR INVESTMENT COMMITTEE – SUBMISSION FORM

1. PROJECT MANAGEMENT

(a)

	Yes	No
Have you described and considered all the possible options?	✓	
In the possible options has the "base case" option been included?	✓	
Have you documented your assumptions (both financial and benefit to the plant)?	✓	
Will the preferred solution be able to satisfy the user requirement specification?	✓	
Have we been able to identify and quantify all inherent risks and structure an acceptable risk response and management plan?	✓	
Has the alignment to EDF been considered?	✓	
Has the relevant technical committee approved the project? (Facilities. Modification Review Board. etc)	✓	
Is the project economically viable?	✓	
If the project is not economically viable. is the motivation clear?	✓	
Are we able to obtain all legal and regulatory requirements?	✓	
Are there suppliers available with the necessary skills, and proven expertise necessary	✓	

PAIA 37(1)(a).Redacted as it contains personal information of staff no longer in Eskom's employement

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4. RECOMMENDATION

The proposal has been approved for execution by the Management Review Board and recommended for approval to the Investment Committee.

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