| CHAPTER 8: EMERGENCY PLANNING | | | |
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| AMENDMENT RECORD | | | |
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| **Rev** | **Draft** | **Date** | **Amendments** |
| 0 | 2 | 01/04/14 | Minor changes following Eskom comments. |
| 0 | 3 | 8/01/14 | Further minor changes in response to Eskom comments; inclusion of a reference and a definition of Koeberg Site. |
| 0 | 4 | 25/03/2015 | Explanation in respect of the Public Exclusion Boundary and EPZs included in Section 8.8. |
| 0 | 5 | 31/03/2015 | Minor typographical corrections as pointed out in review comments |
| 1 | | 16/07/2022 | A major review of Rev 0 was carried out with the focus on the existing Integrated Koeberg Nuclear Emergency Plan and a GEN III new nuclear power station co-located with Koeberg Nuclear Power Station on the Duynefontyn site. |
| 1a | | 15/03/2024 | A review to respond to NNR comments and to include:<br>• updated site information;<br>• information from a review of the KNPS emergency planning technical basis; and<br>• revision 4 of the Integrated Koeberg Nuclear Emergency Plan. |

 

**Executive Summary**

A site safety assessment for an undeveloped greenfield site includes the feasibility of effective emergency response actions on the site with account taken of the characteristics of the site and its regional setting. It includes assessment of any external events that could hinder the establishment of emergency arrangements that have to be in place for a new nuclear power station (NNPS). In the case of the Duynefontyn site, with an operational nuclear power station (NPS), the site safety assessment involves an assessment of the continued feasibility of the established Integrated Koeberg Nuclear Emergency Plan (IKNEP) and the future feasibility of the IKNEP should an NNPS be co-located with the Koeberg Nuclear Power Station (KNPS).

The latest KNPS Periodic Safety Review concluded that overall emergency planning and response arrangements provide for continued safe operation of KNPS, both for present operation and for the duration of the planned Long Term Operation (LTO). Deviations that were identified were categorised as low and it was concluded to not have any significant impact on nuclear safety.

The co-location of an NNPS with KNPS requires an interpretation of the following position statements by the National Nuclear Regulator (NNR) for nuclear installations:

- In the case of multiple nuclear installations on the same site, the accident scenarios of the installation that poses the highest impact should be used to derive the emergency planning zones (EPZs).
- However in the consideration of external events, the integrated impact from all affected installations for a specific accident scenario should be considered. The EPZs for the site may have to be modified should the existing zoning scheme be compromised as a result of the new nuclear installation source term.

The approach to the determination of future feasibility on the Duynefontyn site in view of the NNR position is discussed. The current IKNEP provides for all nuclear and radiological emergencies that may arise from postulated credible nuclear accidents on the Duynefontyn site based on the safety assessment of KNPS LTO safety case.

The DSSR provides information for a Nuclear Installation Site Licence (NISL) but also serves to update the site characteristics to be considered in the KNPS safety assessment reviews. The principal requirements for a NISL are stated in the regulations on licensing of sites for new nuclear installations (Department of Energy, 2011). It is important to consider the NNR position that allows for a multi-stage or a combined license (NNR, 2011). The NISL would consider enveloping characteristics of an NNPS contemplated to be constructed on the site while a Nuclear Installation Licence to site or construct (NIL-to-site/construct) and/or operate would be for a specific NNPS design, i.e. a situation where Eskom has selected a vendor with the design to be built on site. For a NIL-to-site/construct an NNPS the NNR requires sufficient information, in the form of a safety case, covering the full technical safety basis. This is required to enable the NNR to perform a detailed assessment to the extent possible and therefore determine whether the proposed design will meet the requirements and that all safety issues identified during the safety case review will be mitigated at the appropriate stage of the licensing process. This would include a re-assessment of the emergency plan technical basis of the IKNEP to include the NNPS.

No vendor has as yet been appointed and the NNPS technology to be sited and constructed is not known. However, Eskom has specified that it will be of PWR GEN III design and which includes advanced safety characteristics when compared to KNPS. GEN III safety objectives include a significantly lower probability of accidents that may require off-site emergency response and also, should off-site emergency response be required it will be very limited. These objectives are defined in the European Utility Requirements (EUR) objectives for Emergency Planning as follows:

- minimal emergency protection action beyond 800 m from the reactor during releases from the containment, i.e. actions involving public evacuation, based on projected doses up to 7 days, which may be implemented during the emergency phase of an accident, e.g. during the period in which significant releases may occur - This period is generally shorter than 7 days.
- no delayed action at any time beyond about 3 km from the reactor, i.e. actions involving public temporary relocation, based on projected doses up to 30 days caused by groundshine and aerosol resuspension, which may be implemented after the practical end of the releases phase of an accident;
- no long term action at any distance beyond 800 m from the reactor, actions involving public permanent resettlement, based on projected doses up to 50 years caused by groundshine and aerosol resuspension. Doses due to ingestion are not considered in this definition.

This chapter of the DSSR investigates the feasibility of including an NNPS in the IKNEP and whether there will be a need to change the KNPS EPZs and emergency response facilities. EP feasibility must be assessed frequently as discussed in this report. The period until such time that the next licensing phase of an NNPS is entered will see potentially major changes in the region in respect of the following population and emergency planning considerations:

- population density and distribution within the emergency planning zones, with particular focus on existing and projected population densities and distributions in the region, including resident populations and transient populations - These data are kept up to date over the lifetime of the NPP.
- present and future use of land and resources;
- physical site characteristics that could impede the development and implementation of emergency plans;
- populations in the vicinity of the NPP that are difficult to evacuate or shelter (for example, schools, prisons, hospitals);
- ability to maintain population and land-use activities in the protective zone at levels that will not impede implementation of the emergency plans.

These population and emergency planning considerations are routinely assessed as part of the periodic IKNEP review and which must reflect the DSSR information on site specific characteristics pertinent to emergency planning e.g. demography, land and water use and adjacent sea use.

The co-location of an NNPS on the Duynefontyn site will have to consider aspects of multi-unit probabilistic safety assessment and how it may impact on the technical basis of the IKNEP if an NNPS is added to the site. However, it is expected that Eskom's guiding principle for siting of an NNPS will be met. Eskom has committed to the EUR objectives for emergency planning for NNPSs. This commitment and a limited technical assessment of GEN III technology accidents presented in this chapter form the basis of a provisional conclusion that the current EPZs defined in the IKNEP will envelop an NNPS.

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# 8 EMERGENCY PLANNING

## 8.1 Introduction

The fundamental safety objective in the development of any nuclear installation is to protect people and the environment from the harmful effects of ionising radiation. One of the safety principles which form the basis of this objective is to ensure sufficient arrangements and emergency preparedness for effective and adequate response in the case of a nuclear accident (IAEA, 2006). The scope and extent of arrangements for emergency preparedness and response include criteria set in advance for use in determining when to take different protective actions and the capability to take actions to protect and inform personnel at the scene, and if necessary the public, during an emergency. These arrangements are based on emergency planning zones (EPZs). The EPZs represent different areas in which planning for given protective actions is a function of the severity of potential health risks in a zone. Three zones are defined (NNR, 2005):

- The inner emergency planning zone referred to as the Precautionary Action Zone (PAZ) where the risk of deterministic effects is sufficiently high to warrant the establishment of plans for the implementation of pre-emptive protection actions based on plant conditions before a radioactive release or shortly thereafter.
- The intermediate emergency planning zone referred to as the Urgent Protective Action Zone (UPZ) where the risk of stochastic effects is sufficiently high to warrant the establishment of plans to implement protective actions based on environmental monitoring or on plant conditions.
- The outer emergency planning zone referred to as the Long-Term Protective Action Zone (LPZ) where preparations for effective implementation of protective actions to reduce the risk of deterministic and stochastic health effects from long term exposure to deposition and ingestion must be developed in advance.

In keeping with international practice and in line with requirements from the NNR and IAEA, the three zones at the Koeberg Nuclear Power Station (KNPS) consist of areas 5 km (PAZ), 16 km (UPZ) and 80 km (LPZ) in radius.

Eskom intends using the updated Duynefontyn Site Safety Report (DSSR) for an application of a Nuclear Installation Site Licence (NISL) to add either a 2 500 $MW_e$ or a 4 000 $MW_e$ new nuclear power station (NNPS) of the GEN III[1] pressurised water reactor (PWR) type technology as described in ***Chapter 3***. Examples of NNPS designs that are considered are included in

[1] Gen I developed in the period of 1950 – 60, are practically shut down by now, except reactors built and operated in the England. NPP. Gen II of which the KNPS's original design is an example, represents mainly operated reactors in France, Russia and the other European countries, Japan, USA. Life time extension from 30-40 years to 50-60 years e.g. KNPS is being implemented and safety features have since been improved when considering the original as-built NNP. Gen III (and Gen III+) represents advanced reactor types e.g. AP1000 and EPR. Gen IV – E.g. Pebble Bed Modular Reactor and first NPP commissioned in China.

 

***Appendix 8-B***. Significant advancement in research and knowledge of potential nuclear accident scenarios as well as new safety features of NNPSs have allowed a re-evaluation of the traditional emergency planning requirements (EPRI, 2007). GEN III PWR has additional safety features when compared to the existing generation of nuclear power reactors such as KNPS. The probabilities for reactor core damage accidents and the loss of the containment retention function during accidents, have been decreased significantly compared to earlier designs. A GEN III NPS is also provided with the capability to respond to severe accident challenges, resulting in the significantly lower probabilities for accident releases to the environment (Westinghouse, 2004), (AREVA, 2006).

These advances in reactor safety have allowed Eskom to adopt the position that for any NNPS to be sited in South Africa there will be no need for a short-term off-site emergency plan (Eskom, 2009). It must be demonstrated that for any NNPS selected to be built on an Eskom site it is extremely unlikely that quantities of radioactivity will be released to the environment during an accident and compliance with the Eskom EPZs for NNPSs can be demonstrated.

## 8.2 Purpose and Scope

When determining the suitability of a new site (also referred to as a greenfield site) the feasibility of planning an effective emergency response must be demonstrated during a site safety assessment. This normally means that the site safety report (SSR) must identify any physical characteristics unique to the site that could pose a significant impediment to the development and implementation of an Emergency Plan (EP).

A different approach is followed for an existing site where an NPS already operates such as KNPS on the Duynefontyn site. For Duynefontyn the feasibility of the current Integrated Koeberg Nuclear Emergency Plan (IKNEP) is not being questioned in respect of its feasibility (Eskom, 2022). However, an NNPS will be incorporated into the IKNEP and it will have to provide adequate response for the existing KNPS as well as an NNPS.

This chapter of the DSSR investigates the feasibility of including an NNPS in the IKNEP and whether there will be a need to change the KNPS EPZs and emergency response facilities.

## 8.3 Legal and Regulatory Framework

The national legal and regulatory EP framework for nuclear installations is comprehensive and the main safety requirements and criteria are summarised below.

The Department of Minerals and Energy through the National Nuclear Regulator Act, 1999 (Act 47 of 1999) (DME, 2006), requires in Section 38 that, where the possibility exists that a nuclear accident affecting the public may occur, the NNR must direct the relevant holder of a nuclear authorisation to:

 

- enter into an agreement with the relevant municipalities and provincial authorities to establish an EP within a period determined by the Regulator;
- cover the costs for the establishment, implementation and management of such EP insofar as it relates to the relevant nuclear installation(s) or any action contemplated in Section 2(1)(c) of the Act;
- submit such EP for its approval.

The Act requires an effective EP for the protection of persons should a nuclear accident occur. Full compliance with these requirements has to be demonstrated, normally prior to receiving nuclear fuel on site for an NNPS.

The Disaster Management Act, 2002 (Act No.57) and Disaster Management Amendment Act, 2015 (Act No. 16 of 2015), require the Minister to prescribe a national disaster management framework. The framework must reflect a proportionate emphasis on disasters of different kind, severity and magnitude that occur or may occur in South Africa (SA Gov, 2002); (SA Gov, 2015).

Regulations of the Department of Minerals and Energy (2004), No. 287 (SA Gov, 2004) require that the development surrounding any nuclear installation(s) ensure the effective implementation of any nuclear EP that the relevant provincial and/or municipal authorities must:

- develop and implement processes, including associated acceptance criteria, for the conduct of periodic assessment of current and planned population distribution, disaster management infrastructure and new development, to ensure that the EP, as contemplated in Section 38 of the National Nuclear Regulator Act (1999), can be implemented effectively at all times (DME, 2006);
- document the processes contemplated in subsection 4(a) in procedures acceptable to the regulator;
- report to the NNR on the implementation and the results of the monitoring processes at intervals acceptable to the regulator.

International conventions to which South Africa subscribes and for which compliance has to be demonstrated are the following:

- The Convention on Nuclear Safety that requires, for any new nuclear installation, EPs to be prepared and tested before the facility commences operation above a low power level and to be agreed by the regulatory body (Art. 16) (IAEA, 1994) .
- The Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management that also requires each contracting party to ensure that before and during operation of a spent fuel or radioactive waste management facility there are appropriate on-site and, if necessary, off-site EPs. Such EPs should also be tested at an appropriate frequency (Art. 25) (IAEA, 1997).
- The Convention on Early Notification of a Nuclear Accident (IAEA, 1986) that also requires that, in the event of an accident, South Africa shall (i)

 

notify, directly or through the International Atomic Energy Agency (IAEA), those states that are or may be physically affected and the IAEA of the nuclear accident, its nature, the time of its occurrence and its exact location where appropriate; and (ii) promptly provide the states referred to in (i) above directly or through the IAEA, and (ii) the IAEA with such available information relevant to minimising the radiological consequences in those states.

- The Convention on Assistance in the Case of a Nuclear or Radiological Accident (IAEA, 1986) that requires the contracting parties to cooperate with other contracting parties and with the IAEA in accordance with the provisions of this convention to facilitate prompt assistance in the event of a nuclear accident or radiological emergency to minimise its consequences and to protect life, property and the environment from the effects of radioactive releases. This includes the preparation of EPs.

## 8.4 Requirements and Guidelines Documents

The principal requirements in respect of EP for the Duynefontyn site are included in the NNR RD-014 (NNR, 2005). It establishes requirements that shall be met by both holders of and applicants for nuclear installation licences, to ensure adequate provision for the protection of the health and safety of the public and minimize the impact on the environment. RD-014 states that:

- EPs are coordinated with the plans for non-radiological emergencies, both on and off-site, and agreements be established with the local and provincial authorities;
- EPZs are defined for the site;
- adequate supplies, equipment, communication systems and emergency facilities are in place to allow intervening organisations to fulfil their responsibilities and must be identified and kept available for use during emergencies;
- emergency facilities are suitably located to minimise the exposure of emergency workers;
- a laboratory be identified that is able to perform the analysis of radioactive samples.

It is also required that specific provisions are in place for keeping of a record of all persons in a nuclear accident defined area (NNR, 2006) and that a public safety information forum is established by the holder of a nuclear installation licence (NNR, 2004).

NNR guidance document RG-0011 (NNR, 2016a) provides interim regulatory guidance on the siting of new nuclear facilities located on a greenfield site. In the case of the Duynefontyn site the requirements of RD-0014 take precedence as a result of the licensing conditions in KNPS nuclear licence NL-01 (NNR). The guidelines in respect of EP are included in ***Appendix 8-A***..

NNR position paper PP-0015 (NNR, 2012) defines the NNR's position on the use of an acceptable approach and criteria for the development of an emergency plan technical basis (EPTB) in the case of a Nuclear Installation Licence to site or construct (NIL-to-site/construct) an NNPS.

Safety standards for emergency planning feasibility for an NNPS during a site evaluation are provided in IAEA SSR-1 (IAEA, 2019). It defines the following requirement that has to be interpreted for the Duynefontyn site not being a greenfield site:

***'Requirement 13: Feasibility of planning effective emergency response actions***

*The feasibility of planning effective emergency response actions on the site and in the external zone shall be evaluated, with account taken of the characteristics of the site and the external zone as well as any external events that could hinder the establishment of complete emergency arrangements prior to operation.*

*4.41. Requirement 13 applies also to the infrastructure of the external zone where emergency response actions might be warranted.*

*4.42. An assessment shall be made of the feasibility of planning effective emergency response actions in accordance with GSR Part 7* (IAEA, 2015).

*Nuclear installations on the same site and at adjacent or nearby sites shall be considered in the assessment, with special emphasis on nuclear installations that could experience concurrent accidents.*

*4.43. Any causal relationships between external events and the condition of the infrastructure on the site and in the external zone shall be considered when evaluating the feasibility of planning effective emergency response actions.'*

The International Atomic Energy Agency (IAEA) also provides a range of specific EP safety standards and guides and which were considered in the recently completed KNPS 3rd Periodic Safety Review (Eskom, 2021).

## 8.5 Emergency Planning Criteria

### 8.5.1 Generic Intervention and Action Levels

#### 8.5.1.1 IKNEP and NNR RD-014

The IKNEP (Eskom, 2022) includes generic intervention and action levels based on the requirements of NNR RD-014 (NNR, 2005). The NNR RD-014 levels are shown in ***Table 8.1*** to ***Table 8.3***. It is important to note that the feasibility assessment for a co-located KNPS and NNPS considers the generic intervention and action levels included in the current IKNEP and approved by the NNR.

**Table 8.1: Recommended generic intervention levels for Urgent Protective Actions**

| Protective action | Generic intervention level [(a;b)] |
|---|---|
| Sheltering | 10 mSv[(c)] |

 

| | |
|---|---|
| Evacuation | 50 mSv[(d)] |
| Iodine Prophylaxis | 100 mGy[(e)] |

a): These levels are avertable dose, i.e. the action should be taken if the dose can be averted by the action, taking into account the loss of effectiveness due to delays or for other practical reasons, is greater than the figure given.

(b): The levels in all cases refer to the average over suitable samples of the population, not the most exposed individuals. However, projected doses to groups of individuals with higher exposures should be kept below the thresholds for deterministic effects.

(c): Sheltering is not recommended for longer than 2 days. Licensees may wish to recommend sheltering at lower intervention levels for shorter periods or so as to facilitate further protective actions, e.g. evacuation.

(d): Evacuation is not recommended for periods longer than a week. Evacuation may be initiated at lower intervention levels, for shorter periods and also where evacuation can be carried out quickly and easily, e.g. for small groups of people. Higher intervention levels may be appropriate in situations in which evacuation would be difficult, e.g. for large population groups or with inadequate transport.

(e): Avertable committed absorbed dose to the thyroid due to radioiodine.

### Table 8.2: Recommended Generic Intervention Levels for Temporary Relocation and Permanent Resettlement

| Protective action | Avertible dose (a) |
|---|---|
| Temporary relocation | 30 mSv in first 30 days<br>10 mSv in the subsequent 30 days |
| Permanent resettlement | 1 Sv in lifetime |
| (a): The avertable dose applies to an average population being considered for temporary relocation | |

### Table 8.3: Recommended Generic Action Levels for Foodstuffs

| Radionuclides in Foods Destined for General Consumption | kBq/kg |
|---|---|
| Cs-134, Cs-137, Ru-103, Ru-106, Sr-89, I-131 | 1 |
| Sr-90 | 0.1 |
| **Radionuclides in Milk, Drinking Water and Infant Foods** | **kBq/kg** |
| Cs-134, Cs-137, Ru-103, Ru-106, Sr-89 | 1 |
| I-131, Sr-90 | 0.1 |
| Am-241, Pu-238, Pu-239, Pu-240, Pu-242 | 0.001 |

- These levels apply to situations where alternative food supplies are readily available. Where food supplies are scarce, higher levels can apply. They also apply to food prepared for consumption and would be unnecessarily restrictive if applied to dried or concentrated food prior to dilution or reconstitution.

| Radionuclides in Foods Destined for General Consumption | kBq/kg |
|---|---|
| • For practical reasons the criteria for separate radionuclide groups shall be applied independently to the sum of the activities of the radionuclides in each group.<br>• Classes of food that are consumed in small quantities (e.g. less than 10 kg per person per year) such as spices, which represent a very small fraction of the total diet and would make very small additions to individual exposures, may have action levels ten times higher than those for major foodstuffs. | |

NNR RG-0011, which includes the following guidance for EPZ and criteria (NNR, 2016a), would apply to a greenfield site such as Thyspunt:

1) The emergency planning zones should include the following:
   a) an exclusion zone (EZ);
   b) an overall emergency planning zone (EPZ);
   c) a long-term protective action planning zone (LPZ).
2) In determining the emergency planning zones, the following criteria should be used in the definition of the required zones:
   d) EZ – an effective dose (projected) of 100 mSv in the first seven days;
   e) LPZ – an effective dose (projected) of 100 mSv per annum;
   f) overall EPZ – an effective dose (projected) of 1 mSv per annum.
3) The overall EPZ should include a low population zone considering arrangements for urgent protective actions such as iodine prophylaxis, for which an equivalent dose to the thyroid of 50 mSv (projected) should be used in the first seven days.

### 8.5.2 Eskom Position on Emergency Planning Zones for New Nuclear Power Stations compared to Regulatory Expectations for GEN III NPS Designs

#### 8.5.2.1 Eskom EP position for NNPS

Eskom adopted a position that prescribes a standard set of rules enabling a consistent approach to be applied to defining the sizes of the various EPZs for NNPSs and applicable to any of the Eskom sites (e.g. Thyspunt and Duynefontyn) (Eskom, 2009). Eskom's position provides a standard set of emergency planning radii that can be applied to NNPSs as well as the application of the commensurate intervention levels to adequately protect public health and safety.

Acceptance of the suitability of an NNPS would depend on whether its design meets the dose and risk criteria of the NNR and the emergency planning zone (EPZ) sizes of the European Utility Requirements (EUR) (EUR, 2001) apart from also complying with the latest NNR requirements. Any NNPS that will be built must conform to both the NNR regulations and the EPZ sizes of the EUR.

The EUR aims at harmonisation and stabilisation of the requirements to which new GEN III light water reactor NPPs will be designed, built, commissioned, operated and maintained. The aim of the EUR requirements is to promote the harmonisation of NPP aspects, e.g. safety approaches, targets, criteria and assessment methods. The EUR focuses on ensuring that the risk from an NNPS in terms of large off-site releases of radioactivity would be very much lower than that for the current plants such as the GEN II NPSs.

EUR objectives for EP to which Eskom committed can be summarised as follows:

- minimal emergency protection action beyond 800 m from the reactor during releases from the containment (criterion: 50 mSv effective dose) - Emergency protection actions are actions involving public evacuation, based on projected doses up to 7 days, which may be implemented during the emergency phase of an accident, e.g. during the period in which significant releases may occur. This period is generally shorter than 7 days.
- no delayed action at any time beyond about 3 km from the reactor (criterion: 30 mSv effective dose) - These are actions involving public temporary relocation, based on projected doses up to 30 days caused by groundshine and aerosol resuspension, which may be implemented after the practical end of the releases phase of an accident.
- no long term action at any distance beyond 800 m from the reactor (criterion: 100 mSv effective dose) - Actions involving public permanent resettlement, based on projected doses up to 50 years caused by groundshine and aerosol resuspension - Doses due to ingestion are not considered in this definition.

The EPZs for NNPS specified by Eskom are shown in ***Table 8.4*** (Eskom, 2005).

**Table 8.4: Eskom EPZs for NNPS**

| Zone | Size (km) | Action |
|---|---|---|
| Exclusion Zone | 0 – 0.8 | Evacuation (all sectors) based on in-plant conditions. Shelter (all sectors) based on in-plant conditions.<br>Thyroid blocking (all sectors) based on in-plant conditions. |
| Long Term Protective Action Planning Zone | 0.8 to 3.0 | Temporary relocation (based on environmental monitoring). |
| | 0.8 to 40 | Food ban (based on environmental monitoring). |
| Emergency Planning Zone | 0 to 40 | On-going monitoring and public communication. |

The technology of a selected NNPS is deemed acceptable by Eskom if, using a best-estimate approach, it can be demonstrated that no emergency intervention will be required outside the corresponding zone boundary more frequently than 1E-6/y for the site. Eskom states explicitly that if a potential vendor cannot demonstrate compliance to its requirements it will not be given a contract to build (some deviations may be permissible with appropriate justification acceptable to both Eskom and the NNR). These radii of the zones are measured from the extremities of an NNPS footprint. It implies that no off-site evacuation will be necessary for the NNPS reference accidents that serve as a technical basis for its emergency planning considerations.

The position paper clearly states that in the case of Duynefontyn there is no intention '*at the current time'* to change the emergency planning zone sizes in the IKNEP, i.e., PAZ = 5 km, UPZ = 16 km and LPZ = 80 km. In the case of the Duynefontyn site the zones in the current IKNEP will therefore envelope a NNPS.

#### 8.5.2.2 NNR's view of new NPP technologies

Regulatory expectations and views of the NNR in respect of NNPS technologies were expressed in a presentation to the Parliamentary Select Committee on Economic Development and quoted here (NNR, 2010). It is similar to the Eskom requirements and an excerpt from the NNR presentation follows.

*'The NNR considers that, as a global safety goal for evolutionary designs of nuclear installations such as new nuclear power plants, a significant improvement of the safety of the next generation of nuclear power plants at the design stage is necessary compared to existing plants, especially but not limited to better consideration of the problems related to prevention and mitigation of severe accidents.*

*NNPS designs incorporate significant improvements on nuclear safety such as additional redundancy, passive safety features and severe accident countermeasures. These advances significantly enhance the principle of defence-in-depth in terms of multiple barriers, redundancy, accident prevention and mitigation.*

*One major outcome of these new designs is that the emergency planning zones, specifically the UPZ, which is the zone within which evacuation of the public has to be catered for, would in all likelihood be reduced from 16 km in the case of Koeberg, to a much smaller radius which could fall within the property owned by the holder, and thereby to some extent minimize the issue of the control on urban developments which could potentially threaten the feasibility of sites.'*

This latter statement is understood to apply to greenfield sites and not Duynefontyn. NNR PP-0015 (NNR, 2012) provides criteria for greenfield sites and which will also be used in the safety assessment of an NNPS selected for the Duynefontyn site to demonstrate compliance with Eskom requirements; the current IKNEP EPZ will apply in practice. These criteria are stated as follows in NNR PP-0015.

In determining the EPZs, the following criteria should be used in the definition of the required zones:

- Effective dose ( projected ) of 100 mSv over the first 7 days (EZ);
- Effective dose (projected ) of 100 mSv per annum (LPZ);
- Effective dose (projected) of 1 mSv per annum (overall EPZ).

 

The overall EPZ should include arrangements for urgent protective actions such as iodine prophylaxis, for which an equivalent dose to the thyroid of 50 mSv (projected) in the first 7 days should be used. Precautionary protective actions to prevent severe deterministic effects within the Exclusion Zone should be implemented in accordance with the generic criteria in ***Appendix 8-C***. Criteria for protective actions to avoid or minimise severe deterministic effects, and to reduce the risk of stochastic effects, for the determination of EPZs are also included in ***Appendix 8-C***.

## 8.6 The Concept of 'Highest Impact' on the Duynefontyn Site considering Co-located Nuclear Power Stations

NNR PP-0015 states that in the case of multiple nuclear installations on the same site, the accident scenarios of the installation that poses the highest impact should be used to derive the EPZs (NNR, 2012). However in the consideration of the external events, the integrated impact from all affected installations for a specific accident scenario should be considered.

The EPZs for the site may have to be modified should the existing zoning scheme be compromised as a result of the new nuclear installation source term. This position is also included in NNR RG-0011 (NNR, 2016a). To be able to carry out such an assessment requires Probabilistic Safety Analysis (PSA) of the different NPSs. PSA studies for the Eskom reference NNPS that include Duynefontyn site specific external events were not available at the time compiling Chapter 8. However, technical information that supports the assumption that an NNPS consisting of a GEN III technology will present a lower radiological risk than KNPS, without satisfying the detailed PSA requirements for developing a technical basis for an IKEP that includes a NNPS, is available and is presented here.

The PSA of an NPP that commences during the design stage is maintained during the life of an NPP. It is used to evaluate any changes in operating procedures, structures, systems and components (SSCs) as well as changes in site specific external events. Its results have to verify safety criteria for reactor core damage probabilities (PSA Level 1), radioactivity release frequencies (PSA Level 2) and human health risk (PSA Level 3).

PSA Level 2 analysis of accident phenomena identifies the ways in which radioactive releases from an NPP can occur and the magnitude and frequencies of these releases are calculated. The Level 2 PSA provides additional insights into the relative importance of accident prevention and mitigation measures to maintain, for example, reactor containment integrity or the use of other means to control releases. Some typical uses of Level 2 PSA are:

- to gain insights into the progression of severe accidents and containment performance;
- to identify specific vulnerabilities of the containment to severe accidents;
- to identify major containment failure modes and to estimate the corresponding releases of radionuclides;

 

- to provide a basis for the evaluation of off-site emergency planning strategies;
- to provide a basis for the development of specific accident management strategies;
- to provide a basis for the prioritisation of safety research activities.

The enhanced safety design characteristics of a GEN III NPS and information available on PSA Level 2 accident release categories (RCs) following reactor core damage can be compared to those of KNPS. A detailed technical basis for NNPS emergency planning will only be possible when the safety analysis is available for an NL-to-site/construct, i.e. when there is a selected NNPS that includes site characteristics and site-specific external events in its [2]PSA.

An overview of GEN III NPP safety features when compared to KNPS is included in ***Table A8-4*** in ***Appendix 8-D***. A provisional conclusion can be reached that KNPS will present the highest impact when PSA Level 2 accident release categories (RC) and frequencies of KNPS and examples of RCs representative of GEN III NPS are compared. This conclusion will have to be confirmed when a PSA Level 3 is performed for a selected NNPS based on its design that includes consideration of Duynefontyn site characteristics (e.g. external events that include the latest results of site seismic hazard studies). A comparison between KNPS RCs that constitute the current technical basis for the IKNEP (Eskom, 2015), the EPR NPP (AREVA, 2006) and the AP1000 NPP (Westinghouse, 2004) selected as representative of GEN III NPS, are listed in ***Table 8.5*** to ***Table 8.6*** respectively. ***Table 8.8*** contains a comparison between KNPS and GEN III reference NPSs. It shows that the total RC frequencies of a GEN III NPS should be a small fraction of the total KNPS RC frequencies.

It is important to note that a re-assessment of current KNPS EPTB for LTO has since been carried out (Eskom, 2024). The following conclusion reached is quoted; "The re-assessed results of the Koeberg EPTB in accordance the current NNR approved EPTB methodology and approach with the same selection of reference accidents from the 2011 Koeberg PSA baseline (i.e., RC-3 and RC-6 transients) show and conclude that the current PAZ of 5 km and UPZ of 16 km remains adequate and does not provide compelling evidence to justify or support a change in zone radii.".

[2] At the time of compiling Chapter 8 a bounding PSA Level 3 was being developed for the Duynefontyn site and to be submitted to the NNR as part of the DSSR update.

## Table 8.5: KNPS Release Categories

| KNPS Release Category | | Release Frequency (per year) |
|---|---|---|
| RC-1 | Containment integrity is maintained. Containment spray system operable. This results in a slow release of radioactivity into the external environment at the containment design leakage rate. | 7.32E-06 |
| RC-2 | Containment is not isolated, (CI failure). Containment spray system is operable. This results in a slow filtered release of radioactivity into the external environment. | 1.63E-08 |
| RC-3 | Containment is by-passed or not isolated steam generator tube rupture (SGTR or interfacing system loss of coolant accidents (ISLOCA). The containment remains unisolated, resulting in a continuous radioactive release into the external environment. Containment spray function is irrelevant in by-pass accidents, but Containment spray is impaired in CI failure accidents resulting in an unfiltered release. | 3.92E-08 |
| RC-4 | Early containment failure. This corresponds to the total and early loss of containment integrity and a direct release of radioactivity into the external environment within a few hours of the start of the accident. | 1.16E-07 |
| RC-5 | Late containment failure. Containment spray system operable. This results in direct release of radioactivity into the external environment and is considered to occur approximately one day into the accident. | 0.00E+00(1) |
| RC-6 | Late containment failure. Containment spray function impaired. This results in direct release of radioactivity into the external environment and is considered to occur approximately one day into the accident. | 0.00E+00(1) |
| RC-7 | Basemat melt-through. Containment spray system operable. This result in a ground level release of radioactivity into the external environment and is considered to occur several days into the accident. (Koeberg‘s basemat is 6.7 m thick but the area below the basemat is open to the external atmosphere. | 5.02E-08 |
| RC-8 | Basemat melt-through. Containment spray function impaired. This result in a ground level release of radioactivity into the external environment and is considered to occur several days into the accident. | 4.15E-07 |
| Total | | 7.96E-06 |
| (1): Following system modifications the dominant severe accidents for RC-7 and RC-8 in KNPS PSA Level 2 have changed due to the risk being shifted from RC-5 and RC-6 (hydrogen recombiners have | | |

| KNPS Release Category | Release Frequency (per year) |
|---|---|
| been included in RC frequency calculations). The dominant severe accident sequences for RC-7 and RC-8 have been evaluated. | |

**Table 8.6: EPR Release Categories**

| EPR Release Category | | Release Frequency (per year) |
|---|---|---|
| RC1 | Failure of containment isolation (0.442m2 leak) | 1.56E-09 |
| RC2 | Early containment rupture (1m2) at time of RPV failure | 2.58E-08 |
| RC3 | Non-isolated steam generator tube rupture (STGR) – RCS pressure | 2.25E-08 |
| RC4 | Early small containment failure (100cm2),no spray | 3.83E-08 |
| RC5 | Early small containment failure (100cm2), spray | 4.49E-08 |
| RC6a | Large interfacing system Loss of Coolant Accident (LOCA) | 2.26E-09 |
| RC6b | Small interfacing system LOCA | 3.63E-08 |
| RC7 | Late (48h) large containment failure (1m2) | 3.81E-08 |
| RC8 | No containment failure | 3.58E-07 |
| Total | | 5.68E-07 |

**Table 8.7: AP1000 Release Categories**

| AP1000 Release Category | | Release Frequency (per year) |
|---|---|---|
| CFI | Containment failure after core melt <24h | 1.89E-10 |
| CFE | Containment failure during core melt | 7.47E-09 |
| IC | Intact containment leakage | 2.21E-07 |
| BP | Containment bypass | 1.05E-08 |
| CI | Un-isolated containment | 1.33E-09 |
| CFL | Containment failure after core melt >24h | 3.45E-13 |
| Total | | 2.40E-07 |

**Table 8.8: Comparison of the GEN III reference NNP and KNPS two highest RC frequencies**

| NPP | RC Description | | RC frequency per year | %RC compared to KNPS |
|---|---|---|---|---|
| EPR | No containment failure | RC8 | 3.58E-07 | 4.9 |

| NPP | RC Description | | RC frequency per year | %RC compared to KNPS |
|---|---|---|---|---|
| AP1000 | Intact containment leakage | IC | 2.21E-07 | 3.0 |
| KNPS | Containment integrity is maintained. Containment spray system operable. This results in a slow release of radioactivity into the external environment at the containment design leakage rate. | RC-1 | 7.32E-06 | |
| | | | | |
| EPR | Early small containment failure (100 cm2), spray | RC5 | 4.49E-08 | 38.7 |
| AP1000 | CFE | Containment failure during core melt | 7.47E-09 | 6.4 |
| KNPS | Early containment failure. This corresponds to the total and early loss of containment integrity and a direct release of radioactivity into the external environment within a few hours of the start of the accident. | RC-4 | 1.16E-07 | |

It is important to note that Eskom was provided with GEN III design information dating back to 2006. PSA data on the designs of the AP1000 and EPR could have been updated since. The GEN III RC values used in the comparison will also change when Duynefontyn site specific external events are included in the PSA for a selected NNPS. The UK EPR, for example, published the following RC values which are different to the values in the generic design assessment reports provided to Eskom. These RC values are included in ***Table 8.9*** (AREVA, 2012).

**Table 8.9: Characterisation and Frequency of the UK EPR RC (all plant states)**

| RC | Containment Failure Mode | Debris flood | Containment Spray | RC frequency per year | % Core Damage Frequency (CDF) without Spent Fuel Pool (SFP) SFP | % CDF with SFP |
| --- | --- | --- | --- | --- | --- | --- |
| RC 101 | Non-deposition in annulus and Building | | | 1.49E-07 | 21.02% | 20.94% |
| RC 102 | None-annulus and building ventilation | | | 4.84E-07 | 68.30% | 68.06% |
| RC 200 | Isolation failure – in – vessel recovery | Yes | Yes | 9.02E-10 | 0.13% | 0.13% |
| RC201 | Isolation failure – in- vessel recovery | Yes | No | 3.01E-10 | 0.04% | 0.04% |
| RC 202 | Isolation failure | No | Yes | 2.60E-12 | 0.00% | 0.00% |
| RC 203 | Isolation failure | No | No | 3.04E-13 | 0.00% | 0.00% |
| RC 204 | Isolation failure | Yes | Yes | 1.95E-09 | 0.28% | 0.27% |
| RC 205 | Isolation failure | Yes | No | 4.51E-10 | 0.06% | 0.06% |
| RC 206 | All small isolation failures (< 2 inch | | | 4.61E-09 | 0.65% | 0.65% |
| RC 301 | Early | No | Yes | 8.06E-12 | 0.00% | 0.00% |
| RC 302 | Early | No | No | 5.84E-12 | 0.00% | 0.00% |
| RC 303 | Early | Yes | Yes | 1.02E-06 | 1.44% | 1.43% |
| RC 304 | Early | Yes | No | 6.98E-09 | 0.99% | 0.98% |
| RC 401 | Intermediate | No | Yes | 2.67E-11 | 0.00% | 0.00% |
| RC 402 | Intermediate | No | No | 8.37E-12 | 0.00% | 0.00% |
| RC 403 | Intermediate | Yes | Yes | 1.23E.09 | 0.17% | 0.17% |
| RC 404 | Intermediate | Yes | No | 1.09E-09 | 0.15% | 0.15% |
| RC 501 | Late | No | Yes | 6.5E-13 | 0.00% | 0.00% |
| RC 502 | Late | No | No | 3.96E-11 | 0.01% | 0.01% |
| RC 503 | Late | Yes | Yes | 1.27E-09 | 0.18% | 0.18% |
| RC 504 | Late | Yes | No | 3.29E-06 | 4.65% | 4.63% |
| RC 602 | Basemat | | No | 6.57E-10 | 0.09% | 0.09% |
| RC 701 | SGTR scrubbed | | | 4.14E-09 | 0.58% | 0.58% |
| RC 702 | SGTR unscrubbed | | | 5.01E-09 | 0.71% | 0.70% |
| RC 802 | Large ISLOCA unscrubbed deposition in building | | | 3.83E-09 | 0.54% | 0.54% |

 

| RC | Containment Failure Mode | Debris flood | Containment Spray | RC frequency per year | % Core Damage Frequency (CDF) without Spent Fuel Pool (SFP) SFP | % CDF with SFP |
| --- | --- | --- | --- | --- | --- | --- |
| SFP | Spent fuel pool | | | 2.55E-09 | | 0.36% |
| TOTAL CDF without SFP | | | | 7.08E-07 | 100.00% | |
| TOTAL CDF with SFP | | | | 7.11E-07 | | 100.00 |

An example of the calculated low severe accident dose of GEN III NPSs that are expected can be found in the generic design assessment of the UK EPR and quoted here (AREVA, 2012):

***'Release and dispersion: EPR RC 8:***

*According to the safety concept of the EPR the release occurs for the release category RC 8 via the stack. It is assumed that the effective release height is 90 m. For the dispersion, it is assumed that the wind speed is 1 m/s and the dispersion category is normal (dispersion Class D).*

- Radiation dose:

*The following radiation pathways were taken into account:*

- *Direct radiation from the cloud*
- *Inhalation dose*

*The resulting dose in 24 hours at about 800 m distance from the release point is for an adult less than 3 mSv and for a child less than 5 mSv.*

*In the Standard Preliminary Safety Analysis Report additional results of radiological consequences of release category RC 8 are given.*

- RC8 Conclusion:

*The Release Category RC 8 associated to no containment failure is in the order of 2.0E-7/reactor y, and is the most probable release after core damage. It represents more than 90% of the core damage frequency and would lead to a very low dose. This resulting dose within 24 hours at about 800 m distance from the release point, for an adult less than 3 mSv and for a child less than 5 mSv, which is far under the 250 mSv limit.'*

This example of dose assessment, although illustrating the low expected accident dose, is based on United States Nuclear Regulatory Commission (U.S. NRC) requirements which are different to those of the NNR. The context of the 0.25 Sv limit is provided in the U.S. Code of Federal Regulations (U.S Gov.) of which a summary is as follows.

An individual located at any point on the boundary of the exclusion area for any 2-hour period following the onset of the postulated fission product release, would not receive a radiation dose in excess of 250 mSv total effective dose equivalent (TEDE). TEDE is the sum of the effective dose equivalent (for external exposures) and the committed effective dose equivalent (for internal exposures). The early phase (plume phase) TEDE is calculated with the RASCAL code system[3] as the sum of the external gamma dose (cloudshine) from the plume, the committed effective dose equivalent (CEDE), and the external dose over a four-day period from radionuclides deposited on the ground (4-day groundshine dose).

An individual located at any point on the outer boundary of the low population zone, who is exposed to the radioactive cloud resulting from the postulated fission product release (during the entire period of its passage) would not receive a radiation dose in excess of 250 mSv TEDE. The fission product release assumed for this evaluation should be based upon a major accident, hypothesised for purposes of site analysis or postulated from considerations of possible accidental events. These accidents have generally been assumed to result in substantial meltdown of the core with subsequent release into the containment of appreciable quantities of fission products.

## 8.7 An Example of a GEN III NPS EP Requirements and its Application to a Site with Existing NPS

An example of a GEN III NPS EP requirements and its application to a site with existing NPSs can be found in the U.S. NRC regulations. The regulatory requirements applied to GEN III NPS by the U.S. NRC provide reference information when reading section 8.8 on the IKNEP and its future inclusion of an NNPS. This section is concluded with an example of the regulatory assessment of an early site permit (ESP) application for a GEN III NPS to be co-located with an existing NPS.

Co-located licensees are two different licensees whose licensed facilities are located either on the same site or on adjacent, contiguous sites, and that share most of the following emergency planning and siting elements:

- plume exposure and ingestion emergency planning zones;
- offsite governmental authorities;
- offsite emergency response organisations;
- public notification system; and/or
- emergency facilities.

The U.S. Code of Federal Regulations for emergency planning establishes minimum requirements for EPs for use in attaining an acceptable state of emergency preparedness (U.S. Gov). These plans have to be described generally in the preliminary safety analysis report for a construction permit. Major features thereof may be submitted as part of the site safety analysis report for an early site permit. The following items (which are included in the current IKNEP) have to be described as a minimum:

[3] RASCAL developed by the U.S. NRC for Radiological Assessment and Consequence Analysis widely used internationally.

- onsite and offsite organisations for coping with emergencies and the means for notification, in the event of an emergency, of persons assigned to the emergency organizations;
- contacts and arrangements made and documented with local, state, and federal governmental agencies with responsibility for coping with emergencies, including identification of the principal agencies;
- protective measures to be taken within the site boundary and within each EPZ to protect health and safety in the event of an accident; procedures by which these measures are to be carried out (e.g., in the case of an evacuation, who authorises the evacuation, how the public is to be notified and instructed, how the evacuation is to be carried out); and the expected response of offsite agencies in the event of an emergency;
- features of the facility to be provided for onsite emergency first aid and decontamination and for emergency transportation of onsite individuals to offsite treatment facilities;
- provisions to be made for emergency treatment at off-site facilities of individuals injured as a result of licensed activities;
- provisions for a training programme for employees of the licensee, including those who are assigned specific authority and responsibility in the event of an emergency, and for other persons who are not employees of the licensee but whose assistance may be needed in the event of a radiological emergency;
- a preliminary analysis that projects the time and means to be employed in the notification of state and local governments and the public in the event of an emergency - An NPS applicant shall perform a preliminary analysis of the time required to evacuate various sectors and distances within the plume exposure pathway EPZ for transient and permanent populations, noting major impediments to the evacuation or taking of protective actions.
- a preliminary analysis reflecting the need to include facilities, systems, and methods for identifying the degree of seriousness and potential scope of radiological consequences of emergency situations within and outside the site boundary, including capabilities for dose projection using real-time meteorological information and for dispatch of radiological monitoring teams within the EPZs; and a preliminary analysis reflecting the role of the onsite technical support centre and the emergency operations facility in assessing information, recommending protective action, and disseminating information to the public;
- a full participation exercise which tests as much of the licensee, state, and local emergency plans as is reasonably achievable without mandatory public participation shall be conducted for each site at which a power reactor is located;
- an emergency response data system for PWRs which includes the following selected plant parameters:

- primary coolant system: pressure, temperatures (hot leg, cold leg, and core exit thermocouples), sub-cooling margin, pressurizer level, reactor coolant charging/makeup flow, reactor vessel level, reactor coolant flow, and reactor power;
- secondary coolant system: steam generator levels and pressures, main feedwater flows, and auxiliary and emergency feedwater flows;
- safety injection: high- and low-pressure safety injection flows, safety injection flows and borated water storage tank level;
- containment: pressure, temperatures, hydrogen concentration, and sump levels;
- radiation monitoring system: reactor coolant radioactivity, containment radiation level, condenser air removal radiation level, effluent radiation monitors, and process radiation monitor levels;
- meteorological data: wind speed, wind direction, and atmospheric stability.

An example of regulatory review is that of the U.S. NRC staff's technical review of the site safety assessment report (SSAR) and emergency planning information included in the ESP application submitted by Southern Nuclear Operating Company (SNC) for the Vogtle Electric Generating Plant (VEGP) site.  SNC applied for an ESP that could support an application to construct and operate additional Westinghouse AP1000 NPS with a total nuclear generating capacity of up to 6800 megawatts thermal ($MW_t$). The ESP site is a sub-area on the total VEGP site; a situation similar to the sub-area on the Duynefontyn site where the NNPS will be located. The Units 3 and 4 proposed at the time of the ESP submission assessed the VEGP site adjacent to and west of two existing nuclear power reactors operated by [4]SNC (U.S. NRC).

VEGP proposed in the SSAR, as part of an ESP application, a complete and integrated emergency plan. VEGP developed the plan using the existing VEGP Emergency Plan for units 1 and 2. The proposed ESP site footprint consists of a portion of the existing VEGP site and is located immediately adjacent to VEGP Units 1 and 2. Therefore, little distinction exists between the VEGP site and the ESP site for purposes of emergency planning. The ESP application took advantage of the emergency planning resources, capabilities, and organisation that existed at the VEGP site.

The U.S. NRC did not identify any significant differences between the emergency planning elements proposed in the SSAR and the existing VEGP Emergency Plan elements relied on in the SSAR. It was found that, for purposes of identifying physical characteristics that could pose a significant impediment to developing emergency plans for the proposed two additional reactors at the VEGP site, there is little distinction between the existing

[4] At the time of writing this report Units 3 and 4 have both been successfully connected to the electric grid.

VEGP site and the ESP site. Because the existing VEGP site includes the ESP site, U.S. NRC found that the SNC's use of the then current estimated time to evacuate (ETE) for the VEGP site in the ESP application was acceptable and appropriate.

## 8.8 The Integrated Koeberg Nuclear Emergency Plan (IKNEP)

### 8.8.1 An overview of the IKNEP

The IKNEP serves to establish an organised emergency response capability in the event of a nuclear accident. IKNEP, as defined in (Eskom, 2022), is based on the Eskom emergency preparedness and response requirements (Eskom, 2005). The objectives of the IKNEP are:

- to establish an organised emergency response capability for timely, co-ordinated action of intervening organisations in an event of a nuclear accident;
- to describe the capabilities, responsibilities and authorities of intervening organisations and a concept for integrating the activities in the interest of public health and safety.

Its scope includes any nuclear emergency that has or is expected to have a radiological effect within or outside the boundaries of the KNPS that could require an emergency response by several government organisations. The safety assessment that forms the basis of IKNEP is described in (Eskom, 2022) as follows: "The scope of the IKNEP and extent of the planning zones are based on the Koeberg Emergency Plan Technical Basis, approved and issued by the NNR via letter k12131.1N (dated 28 February 2005) and on the legal requirements contained in the National Nuclear Regulator Act, 1999 (Act No. 47 of 1999) and the Disaster Management Act, 2002 (Act No. 57 of 2002) and the Disaster Management Amendment Act, 2015 (Act No. 16 of 2015) .The overall Integrated Koeberg Nuclear Emergency Plan is based on the abovementioned legislation, relevant regulations and NNR requirements."

IKNEP provides compliance to the NNR requirements from the technical basis for emergency planning. These requirements are included in Table 8.10.

**Table 8.10: NNR Requirements and the Technical Basis for the IKNEP**

| Zone | Size (km) | Action | Implementation time (hours) | Justification |
|---|---|---|---|---|
| PAZ | PEB-5 | Evacuation (all sectors) based on in-plant conditions | 4a | Reduces the risk of deterministic effects by pre-emptively evacuating out to a radius where deterministic mortality |

| Zone | Size (km) | Action | Implementation time (hours) | Justification |
|---|---|---|---|---|
| | | | | effects may not occur LG-1036 and IAEA TECDOC 953 and 955 |
| UPZ | 5-16 | Shelter (downwind sectors)<br><br>Evacuation based on in-plant conditions leading to 12-16 hour advance warning<br><br>Thyroid blocking (downwind sectors) | 4[a]<br><br>16<br><br>10[a] | Reduces the risk of stochastic effects by pre-emptively sheltering downwind and then evacuating based on prevailing conditions (e.g. plant degradation and environmental monitoring)<br>LG-1036 and IAEA TECDOC 953 and 955<br><br>In line with international practice |
| LPZ | 0-80 | Relocation (based on environmental monitoring)<br><br>Food ban (based on environmental monitoring) | Long term action<br><br>Long term action | Reduces the risk of stochastic effects from long term exposure to deposition and ground shine<br>LG-1036 and IAEA TECDOC 953 and 955 |

a) Implementation time is measured from the time when the protective action is recommended by the Emergency Controller and is accepted by the CoCT Disaster Operations Centre.

The evaluation of NNPS EP aspects will be be reviewed against the IKNEP scope in the next licensing stage. The next licensing stage will include a selected NNPS technology and an NNPS SAR. It will include PSA information that incorporates Duynefontyn site specific external hazards, providing PSA level 2 release categories and source terms that can be used to confirm compliance with Eskom requirements for NNPSs (Eskom, 2009).

The operational responsibilities of the different intervening organisations relating to implementation of the IKNEP and illustrated in *Error! Reference source not found.* are addressed in a detailed work flow responsibility matrix in (Eskom, 2022). The responsibilities of national, provincial and local intervening organisations relating to nuclear emergencies are addressed in the Disaster Management Act, 2002 (Act No. 57 of 2002) and the National Nuclear Disaster Management Plan (SA Gov, 2002). The responsibilities of Eskom and the National Nuclear Regulator relating to Integrated Koeberg Nuclear Emergency Plan are addressed in the National Nuclear Regulator Act (SA Gov, 2004).

Effective response to an emergency generally requires mutually supportive and integrated emergency planning at three levels:

- operator;
- off-site;
- international level.

The IKNEP therefore incorporates:

- Eskom Koeberg;
- Eskom Regional;
- Eskom Megawatt Park;
- the City of Cape Town;
- regional, provincial, and national disaster management teams;
- other local supporting organisations such as NECSA, the NNR, and international support from the IAEA, Framatome, and EDF.

 

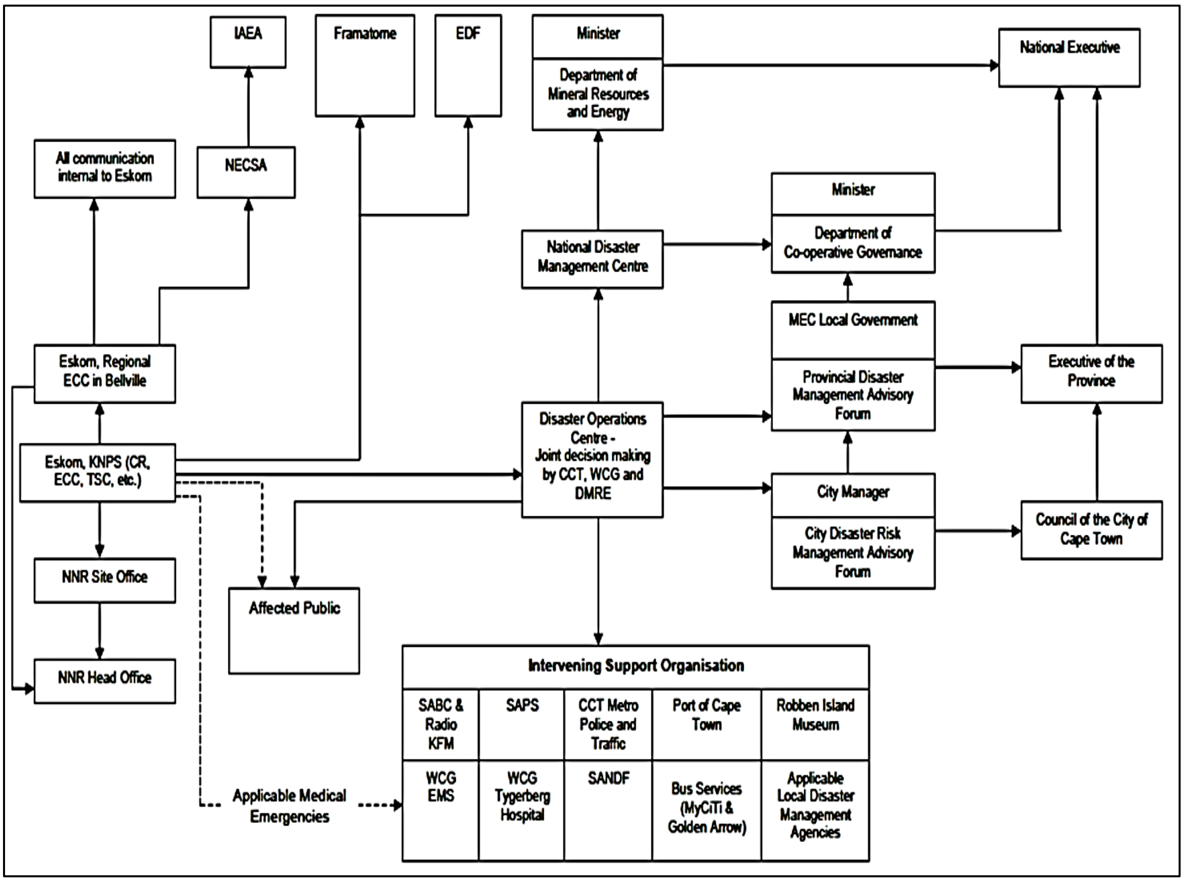


**Figure 8-1: The principal lines of IKNEP communication**

### 8.8.2 IKNEP and its Review against External Events after Fukushima Daiichi

#### 8.8.2.1 A brief summary of events at Fukushima

A brief summary of the accident is provided to illustrate the extreme conditions during which an EP has to be implemented (NEA, 2021).

On 11 March 2011, Japan was struck by a massive earthquake which initiated a tsunami that inundated a large portion of the east coast of Japan. The tsunami caused significant devastation and loss of life. The tsunami also led to a severe accident at the Tokyo Electric Power Company (TEPCO) Fukushima Daiichi Nuclear Power Plant. Post-accident analyses have verified that the radiation from the accident has not led to any direct impact on human health. However, the health and well-being of more than 150 000 people living in surrounding areas was affected to different degrees (including some early deaths) as a result of evacuations from the area due to both the tsunami and the nuclear accident, lack of access to health care or medicines, stress-related problems, and other causes. The accident also caused disturbance to the daily life of many people and businesses and other activities.

 

The initial state of the Fukushima Daiichi Nuclear Power Plant immediately after the earthquake and tsunami was one of devastation. Inundation of the site by the tsunami blocked roads and access routes, and caused extensive damage to the buildings. In this early stage, only Units 5 and 6 retained alternating current (AC) power. The diesel generators for Units 1-4 had failed and no off-site power sources were yet available.

The devastation was subsequently increased by the hydrogen explosions in Units 1, 3 and 4. Moreover, the fuel in three reactors (Unit 1, 2 and 3) had melted and some of the resulting corium material had migrated from the reactor pressure vessels into the containment vessels. Importantly, there were high radiation levels around the site both from direct radiation shine and from airborne radioactive contamination. This hampered recovery operations, limiting the amount of time workers could spend close to high radiation sources, and work in all areas required the use of protective clothing and respiratory protection.

- The first priority during an initial recovery stage was to stabilise the site to reduce potential risks to the site personnel and the surrounding communities. Only when the site was made sufficiently safe could consideration be given to decommissioning. This stabilisation included the following: Restoring electrical power to the site from off-site sources;
- arranging robust cooling of the reactor cores and spent fuel pools (SFPs);
- establishing criticality monitoring and protection;
- clearing access routes;
- reinforcing structures where necessary to ensure they were safe;
- installing air filtration units in buildings; and
- stabilising contamination on surfaces to reduce re-suspension of radioactive particles.

A particular problem for site personnel during the initial phase of the accident was the increasing volume of highly contaminated water accumulating on site and overflowing to the sea.

The operators faced a daunting task to stabilise the reactors to reach what was deemed to be a “cold shutdown condition” where the reactor pressure vessel (RPV) temperature at the bottom generally was below 100℃ and the public radiation exposure from any additional release was significantly minimised. This condition, which was achieved in December 2011, was an important milestone.

#### 8.8.2.2 The KNPS External Events Review Post-Fukushima

Eskom carried out a safety re-assessment of KNPS following the Fukushima-Daiichi nuclear accident. It focussed on external events predominantly in the beyond design basis domain, as directed by the NNR. The safety re-assessment carried out by External Event Review Team (EERT) evaluated the provisions of the design basis concerning extreme natural phenomena and combinations of external events appropriate for the site (Eskom, 2011), (Eskom, 2015).

The adequacy of emergency management and response provisions were assessed, with a focus on:

- emergency management actions and preparedness following worst-case accident scenarios;
- radiological monitoring following nuclear accident involving radiological releases;
- public protection emergency actions;
- communication and information flow in an emergency situation.

The main finding was the absence of a design basis for the facilities and equipment being used to implement, coordinate, and support the IKNEP. It was proposed that a design basis be developed for the facilities and equipment being used in IKNEP. This design basis has to include consideration for external events that could potentially challenge the ability to implement the emergency plan.

The seismic capability of the emergency control centre (ECC) was found to be substantial as a result of the method of construction. The capability of the ACP2 building constructed on top of the ECC was a concern. The ECC has two entrances, one from inside ACP2, the other from outside. If the ACP2 building suffers structural damage, access to the emergency control centre could be impaired. Proposals included the following, for example:

- the side access to the Koeberg emergency control centre be protected against potential blockage caused by structural damage from the ACP 2 facility;
- the Koeberg ECC be adequately sealed to protect the building against any external flooding as well as the plant sewerage system;
- the capability of the services in the Koeberg ECC be improved to prevent failure during a seismic event e.g. a diesel generator be installed in a more suitable location to power the ECC during a severe external event.

It was also considered that should both Koeberg units fail simultaneously, emergency personnel resources would be inadequate. Proposals to enable Koeberg to deal with such an event have been made. Similar considerations will be required for the inclusion of an NNPS in the IKNEP.

### 8.8.3 IKNEP Periodic Safety Review

The KNPS periodic safety review in 2021 (Eskom, 2021) included the IKNEP. The objectives of the review of emergency planning, in line with the National Nuclear Regulator guidance in NNR RG-0028 (NNR, 2019), was to determine whether KNPS has adequate plans, staff, facilities, and equipment in place for dealing with emergencies; and arrangements to respond to emergencies requiring coordination with local and national authorities and are regularly exercised to ensure effectiveness.

It is demonstrated that there is compliance against applicable national and international requirements through the review of 216 consolidated requirements covering the entire scope of emergency planning at KNPS. It concludes that KNPS has in place adequate plans, staff, facilities and equipment for dealing with emergencies; and arrangements have been adequately coordinated with the arrangements of local and national authorities and are regularly exercised. The safety review also concluded that emergency planning and response arrangements are adequate to ensure continued safe operation of the plant, both currently and for the duration of LTO.

The safety review raised deviations that primarily deal with the following:

- inadequacies in the technical basis for EP[5];
- inadequate arrangements and emergency plan staffing resources to maintain functionality of the emergency response for failure of both units simultaneously or in post severe on-site and off-site infrastructure damage scenarios;
- unreliability in the pager system in notifying emergency response organisation staff.

The safety significance of the deviations were all categorised as low and it was concluded that the deviations do not have any significant impact on nuclear safety. One of the proposed safety improvements required the revision of the KNPS EPTB to consider multi-unit accident conditions. This aspect will again have to be assessed for an NNPS co-located with KNPS on the site.

### 8.8.4 IKNEP Extension for Co-located KNPS and NNPS

An NNPS on the Duynefontyn site will be constructed and operated under its own nuclear licence. The U.S. NRC has the following EP requirements for co-located nuclear facilities such as KNPS and an NNPS (U.S. NRC).

*Co-located licensees are two different licensees whose licensed facilities are located either on the same site or on adjacent, contiguous sites, and that share most of the following emergency planning and siting elements:*

- *plume exposure and ingestion emergency planning zones;*
- *offsite governmental authorities;*
- *offsite emergency response organizations;*
- *public notification system; and/or*
- *emergency facilities.*

*Each licensee shall:*

1) *conduct an exercise biennially of its onsite emergency plan;*

[5] The EPTB for KNPS LTO has been reviewed and reported in (Eskom, 2024).

2) *participate quadrennially in an offsite biennial full or partial participation exercise;*
3) *conduct emergency preparedness activities and interactions in the years between its participation in the offsite full or partial participation exercise with offsite authorities, to test and maintain interface among the affected state and local authorities and the licensee - Co-located licensees shall also participate in emergency preparedness activities and interaction with offsite authorities for the period between exercises*.

Examples of specific IKNEP facilities and services that may require review and/or changes when an NNPS is added to the site, are (Eskom, 2022):

- Emergency Control Centre for each co-located NPS (ECC KNPS and ECC NNPS);
- Alternate Emergency Control Centres (AECCs);
- Technical Support Centres (TSCs);
- Alternate TSCs;
- Damage Control Stores;
- Environmental Survey Laboratory;
- Koeberg Fire Station;
- vehicles allocated to the Emergency Plan for radiological surveillance, or identified as being required to support emergency response;
- site muster stations;
- redundant communications system in all Emergency Control Centres.

It will also be important to evaluate the potential hazards to and management of safety of the KNPS operating units resulting from NNPS construction activities.

## 8.9 IKNEP Technical Aspects to be Considered

### 8.9.1 IKNEP Inclusion of an NNPS

***Section 8.6*** presented an argument without presenting a detailed technical basis as described NNR PP-0015 (NNR, 2012), that the current EPZs should envelop an NNPS. A detailed technical basis will be developed during the next licensing phase when a successful vendor for an NNPS has submitted a safety analysis report as is required for a NIL-to-site/construct (NNR, 2011). Calculation of EPZ values according to PP-0015 requires the NNPS PSA Level 2 release categories and associate source term data. The main requirements from NNR PP-0015 that will be applied to the selected NNPS design are summarised[6].

The size of each EPZ should be such that it is not credible that the protective action(s) considered for implementation in the EPZ would be needed outside

[6] A plant parameter envelope compiled for the DSSR update (Eskom, 2022) does not currently include information that allows implementation of PP-0015 at this early licensing stage.

the EPZ. A credible accident is an accident that could be expected to occur once in a million years i.e., has a probability of occurrence of 1E-6/y.

Based on an analysis of the dose calculated for RCs and their respective frequencies obtained from a PSA the likelihood of exceeding the generic criteria for the protective action(s) considered for implementation in the EPZ at any distance from KNPS/NNPS can be determined. For each RC the radius R is determined at which the generic criteria for the protective action being considered is exceeded. The results are tabulated in descending order of R and the frequency for each RC. For each RC the sum over the frequencies (i.e., cumulative frequency of exceedance) is determined of the RCs exceeding the corresponding value of R. This represents the cumulative frequency of exceedance F of the RCs which would require the implementation of the protective action beyond the distance R. Graphs are developed of the cumulative frequency of exceedance F as a function of the distance R for protective actions, e.g. evacuation. This graph will always decrease with increasing radius R as the likelihood for exceeding any particular dose will get smaller at larger distances. The curve in this graph represents the generic criteria for the protective action being considered. The value of R at which the cumulative frequency of exceedance “threshold” value of 1E-6/y is reached represents the desired radii associated with the generic criteria for the protective action. The likelihood of having to implement a protective action beyond this point (distance) is 1E-6/y. The reference accident(s) would then be the RC or group of RCs closest to the point on the graph. In the consequence calculations, no credit should be taken for countermeasures such as sheltering, evacuation, iodine prophylaxis, relocation, food bans or decontamination.

The co-location of NNPS on the Duynefontyn site poses technical challenges when performing a safety assessment which will have to consider multi-unit PSA (MUPSA) for future technical basis of the IKNEP that includes an NNPS. Most of the existing PSA studies focused on two reactor unit NPS sites. Since the number of multi-unit sites with numbers in excess of four unit NPS is increasing internationally, there is much focus on the development of validated practical approaches to the related MUPSA (Dong-San, 2018). A brief overview of MUPSA is provided below (IAEA, 2018).

At a multi-unit site, the design basis for different reactors is often not the same. The conditional probability of core damage given occurrence of a hazard that challenges nuclear safety vary considerably among reactor units as a result of the difference in the design basis. This needs to be taken into account in screening the hazard using the hazard frequency criterion. Screening using bounding analysis based on CDF or large early release fraction (LERF) can be done only for single units. For a multi-unit site, the analysis needs to take into account the impact that a hazard may have on multiple units, the redundancy and sharing of systems between the units, and the impact that core damage in one unit will have on emergency response at other units. A bounding or demonstrably conservative analysis is used to show that either the hazard frequency is too low or the damage probability in other units is acceptably small, otherwise a detailed multi-unit PSA needs to be performed.

For typical external hazards requiring bounding analysis, the following approach could be taken: For high wind, screening use bounding analysis based on the low hazard frequency for both single unit and multi-unit sites. For external flooding a detailed PSA is performed. For transportation accidents, screening is based on low hazard frequency.

### 8.9.2 Spent Fuel Storage and KNPS Thermal Power Uprate

The emergency provisions for potential accidents involving the proposed Transient Interim Storage Facility (TISF) is assumed to be enveloped by the IKNEP, as is the case for the Cask Storage Building currently containing spent nuclear fuel. NNR RG-0020 states that spent fuel dry cask storage related accidents are not expected and are unlikely to result in the release of significant radiological material off-site and potential doses in excess of the generic criteria requiring the implementation of urgent protective actions (NNR, 2018).

The potential impact of the Thermal Power Uprate (TPU) and Steam Generator Replacement (SGR ) projects on the PAZ and UPZ was included in the re-assessment of the Koeberg EPTB (Eskom, 2024). The current PAZ of 5 km and UPZ of 16 km remain adequate.

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## 8.10 Aspects of IKNEP Implementation that Require Further Assessment

### 8.10.1 Estimated Time to Evacuate and the Transport Evacuation Model

An updated analysis is required of the time to evacuate various sectors and distances within the EPZ plume exposure pathway for transient and permanent populations, using the most recent demographic and census data. Updated evacuation time estimates (ETEs) are critical for offsite protective action strategies. The IKNEP depends on the accuracy of the ETE analysis to support evacuation decisions; therefore, it should be reviewed periodically to identify changes that may have occurred. At the time of compiling this report the final results of the national census carried out in 2022 are awaited. . The results will provide updated population data input for the ETE and Traffic Evacuation Model (TEM) for the IKNEP[7].

A reference that provides guidance for the periodic review of an ETE can be found in the U.S. Code of Federal Regulations (U.S. Gov). A summary is provided as follows.

Whenever population increases occur that cause ETE values to materially increase, the ETE analysis should be updated. In the Unites States an NPS licensee has to provide an updated ETE analysis to the U.S. NRC within 365 days of:

[7] STATS SA commenced a population census in February 2022. The previous census took place in 2011

- availability of the decennial census data, and
- when a population increase within the EPZ causes certain ETE values to increase by 25 per cent or 30 minutes, whichever is less, as described below.

Licensees have to estimate EPZ permanent resident population changes at least annually during the years between decennial censuses using census data. These estimates have to occur no more than 365 days apart. Province/local government population data may also be used, if available. Licensees must maintain these estimates available for regulatory inspection during the period between censuses and must submit these estimates to the regulator with any updated ETEs.

If at any time during the decennial period, the population increases so that the ETE for EPZs (in the case of Duynefontyn the PAZ and UPZ) increases by 25 per cent or 30 minutes, whichever is less, for the scenario with the longest ETE, the ETE analysis must be updated to reflect the impact of that population increase. Licensees should perform a population sensitivity study during development of an ETE to determine the population value that will cause ETE values to increase by 25 per cent or 30 minutes, whichever is less. The sensitivity study should be performed and included with a baseline ETE.

### 8.10.2 IKNEP and Combined Emergencies

Apart from consideration of a MUPSA for the EP technical basis, multi-unit site requires detailed consideration of actual emergency response actions. The consequences of the Fukushima Daiichi accident included severe core damage to the three operating reactor units, a containment breach on at least one of the reactors and a large release of radioactive material, the magnitude of which was only exceeded during the Chernobyl accident (IAEA, 2019). Emergency response teams were severely challenged in efforts to prevent even larger releases, as the accident exposed weaknesses in the existing accident management capabilities to cope with a multi-unit accident with extended station blackout conditions. Fortunately some units were down for maintenance and refuelling and one emergency diesel generator on the site was undamaged. Reactor core damage could potentially have included all six units, with the potential for even larger releases than those experienced.

The work to develop emergency response and accident management provisions for multi-unit accidents is still evolving internationally. Accident management and emergency planning guidelines are currently based on the assumption that accidents only occur on one reactor unit at a time. For some multi-unit accidents, the initial plant conditions, initiating events and plant responses to the initiating events may follow similar accident sequences. However, different accidents can create new challenges. MUPSA can provide risk insights that can be incorporated into emergency planning.

In the case of a combined emergency the impacts on the NPS and activities, on the community and its infrastructure and on the overall response to the nuclear emergency, can be severe and can challenge the ability of all response organizations as illustrated during the Fukushima accident. Additional arrangements are needed to ensure an effective preparedness and response for nuclear or radiological emergency combined with other incidents or emergencies. A first step in developing EPR arrangements for combined emergencies is to perform a hazard assessment. The hazard assessment needs to include the identification of all hazards and their potential consequences from events such as the following (IAEA, 2020):

- a combination of a nuclear or radiological emergency and/or a conventional emergency, natural event or security event (especially including those that can trigger the nuclear or radiological emergency);
- events that could occur at the NPS of low probability or otherwise not considered in the design basis;
- events affecting several facilities and activities simultaneously, and their interactions;
- events that affect wide areas and/or impair capabilities to support the emergency response;
- events that might affect other states;
- events in other states that might affect local territories.

The results of the hazard and risk assessment enable a graded approach to the preparation of arrangements that are commensurate with the types of hazard identified and their potential consequences. Additionally, based on the hazards and potential consequences, protection strategies can be developed, justified and optimized for taking effective protective actions and other response actions.

Thus, the hazard assessment is a necessary building block for developing, maintaining and coordinating arrangements for preparedness and response to combined emergencies, along with arrangements for preparedness and response to other types of incidents or emergencies.

Ensuring effective preparedness and response for a combined emergency requires the development and maintenance of an all-hazard national emergency management system (EMS) that includes communications, coordination, cooperation and integration of operating, local, regional and national emergency response organisations. An all-hazard national EMS provides the foundation for an effective and efficient state response to any emergency and harmonisation of arrangements with neighbouring states and the international community.

### 8.10.3 Economic Impact

A severe accident resulting in a general emergency with off-site radioactive contamination may have a significant economic impact. The safety objectives of GEN III NPS when compared to earlier NPP designs such as KNPS include a limited potential economic impact on a region following an accident. The possible restriction on the consumption of foodstuff and crops should be limited in terms of timescale and surface area.

 

Various cost elements are included in the evaluation of the total cost of an accident. These cost elements must reflect the socioeconomic environment of a site in terms of agriculture, tourism, fishing, retail and trading and civil installations. Information on the socioeconomic environment is provided in the Nuclear-1 Environmental Impact Assessment (EIA) (Eskom, 2011). However, it represents conditions at the time the EIA was carried out (from 2010 to 2011). The costs of both short-term and long-term consequences and countermeasures must be accounted for in an economic impact model. Examples of countermeasures that are considered in terms of costs are briefly described here without attempting to develop a detailed economic impact model for the site (EC, 2002).

#### 8.10.3.1 Population Movement

The countermeasures that could affect people through restrictions on movement are sheltering, evacuation and relocation to low radiation or uncontaminated areas. These countermeasures may be judged by the relevant authorities to be unnecessary during an emergency at the nuclear installation but there could still be non-controlled behaviour by people, such as voluntary population movements. This would be difficult to account for in any economic impact model. The typical costs arising from a countermeasure which involves population movement, without excluding other possible impacts, can be mainly associated with the following:

- transport away from and back to affected areas;
- temporary accommodation and food;
- supervision of the evacuated area and monitoring of people;
- loss of income for people unable to reach their workplace;
- lost capital value and investment on land and property;
- psychological effects of stress and upheaval which are indirect costs to the society and difficult to estimate.

#### 8.10.3.2 Agricultural Restrictions and Countermeasures

Costs will result from restrictions on the production or consumption of foodstuffs inside the EPZs, because the levels of radioactivity in the food exceed regulatory criteria, or those arising from other food countermeasures which are implemented to reduce the levels of contamination in agricultural products. The costs to be considered depend on the agricultural countermeasures implemented. The main ones concern:

- the cost of the food production lost - This cost has to be considered for all countermeasures where the banning of food is necessary. An indicator of the cost is the loss for the producer due to not being able to sell the products. The unit cost of food production lost can be evaluated through the average selling price of the food concerned. It can also be necessary to consider the cost of elimination/destruction of the contaminated foods, as well as the costs of final waste storage for the residues of the destruction process.

 

- the cost of food processing - This cost is related to the countermeasure consisting in processing the contaminated food into a derived food product to decrease the concentration of radioactivity, for example, processing whole wheat into flour or cow's milk into cheese. One way of estimating this cost consists of evaluating the difference between the selling price of one unit of the new product and the selling price of the total amount of raw food needed to produce one unit of the new product.
- the cost of food storage - This cost must be considered when the food is stored for long period of time in order to decrease the radioactivity. The cost will depend on the type of storage implemented (ambient temperature, refrigerated or freezing storage).
- the cost of alternative supplies - This cost concerns the feeding of animals with non-contaminated feed, or when animals are removed from contaminated pasture, and the replacement of foodstuff for the population. The evaluation of this cost considers the selling price of the unit animal feed or foodstuff, as well as cost of transportation from the production area to the contaminated area of concern.
- The cost of lost capital value of land and stock - This cost arises when the population is relocated or if long-term restrictions are imposed on the land use. The value of agricultural land per unit area is used.

#### 8.10.3.3 Decontamination of Land Areas and Structures

Decontamination is performed to reduce ambient radioactivity levels to pre-accident levels where possible or to a predetermined reference value. This countermeasure influences the duration of the ban on any evacuated area, but also the degree of radiation exposure of the population. The costs of decontamination consist of:

- cost of the cleaning process, including the necessary equipment and materials, as well as the disposal and transportation of the generated waste;
- cost of labour;
- cost of health effects induced in the workforce;
- decontamination costs determined by the level of decontamination or dose rate reduction aimed for and on the type of environment being decontaminated.

#### 8.10.3.4 Cost of Radiation-Induced Health Effects

The estimation of the economic cost resulting from the predicted number of health effects is an important part of the assessment of the full economic consequences of an accident. It includes direct health care costs and indirect costs due to the loss of incomes during treatment and convalescence or of the total expected future incomes in the case of death. There are also non-monetary costs such as pain, grief and suffering associated with health effects.

The psychological distress is an important effect in itself. A sudden change in living conditions for those affected by the countermeasures can also lead to an increase in cases of stress related illness and the associated cost thereof.

## 8.11 Monitoring Programme

The current IKNEP is maintained in respect of NNR requirements. Monitoring of characteristics of the Duynefontyn site that may be important to the continued feasibility of the IKNEP includes (DME, 2004):

- monitor the current and planned population distribution, disaster management infrastructure and new development to ensure that the EP, as contemplated in section 38 of the act [Republic of South Africa (1999), National Nuclear Regulator Act,1999.Act No. 47 of 1999. Pretoria] can be implemented effectively at all times;
- report to the NNR on the implementation and the results of the monitoring processes at intervals acceptable to the NNR;
- maintain up to date ETE and TEM.

Prior to construction of an NNPS the following measures have to be completed:

- monitoring of infrastructure design and development at this early stage so that the feasibility of the IKNEP remains valid;
- confirmation of EPZs with information from the safety analysis and postulated accident source terms from the final selected NNPS technology;
- assessment and definition of IKNEP changes required.

### 8.11.1 Prior to NNPS Operation

Prior to operation the following actions have to be completed:

- Prior to receipt of nuclear fuel for the NNPS, the IKNEP NNPS may have to be tested and to be determined by the NNR (NNR, 2005).
- Submission of the IKNEP revised in respect of the NNPS for the NNR approval.

### 8.11.2 During NNPS Operation

Once the new nuclear installation(s) commences operation, the IKNEP has to be reviewed, tested and updated regularly as is currently the case for IKNEP.

Training and emergency drills have to be performed that include the NNPS.

## 8.12 Management System

The evaluation of emergency planning feasibility for an NNPS co-located with KNPS on the Duynefontyn site has been conducted in line with the management system for this SSR (presented in detail in ***Chapter 10***) and Eskom's management system.

The discussion of the NNR guidelines on licensing of sites, NNR RG-0011 (NNR, 2016a) is included in ***Appendix 8-A***. In revision 1 of this chapter,E compliance was measured against NNR RG-0011. However, the requirements for the site emergency response remain those in NNR RD-0014 and upon which IKNEP has been approved by the NNR (NNR, 2005).

## 8.13 Conclusions

The co-location of NNPS on the Duynefontyn site will have to consider aspects of multi-unit probabilistic safety assessment and how it may impact on the technical basis of the IKNEP as well as changes required for onsite and off-site EP systems and arrangements if an NNPS is added to the site. However, it is expected that Eskom's guiding principle for siting of an NNPS will be met. It is therefore unlikely that the Duynefontyn EPZs will have to change because of an NNPS.

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EP feasibility must be assessed frequently as discussed in this report. The period until such time that the next licensing phase of an NNPS is entered will see potentially major changes in the region in respect of the following population and emergency planning considerations:

- population density and distribution within the protective zone, with particular focus on existing and projected population densities and distributions in the region, including resident populations and transient populations. - These data are kept up to date over the lifetime of the NPP.
- present and future use of land and resources;
- physical site characteristics that could impede the development and implementation of emergency plans;
- populations in the vicinity of the NPP that are difficult to evacuate or shelter (for example, schools, prisons, hospitals);
- ability to maintain population and land-use activities in the protective zone at levels that will not impede implementation of the emergency plans.

These aspects of feasibility apply to IKNEP irrespective of a NNPS being added to the site.

 

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## Appendix 8-A: NNR RG-0011 –Section 9: Assessment of Regional Conditions for Zoning and Emergency Planning

The guidelines in RG-0011 are listed in respect of an NNPS on the site. RD-0014 is the principal NNR regulatory document against which compliance for the Duynefontyn site has to be demonstrated, a requirement in terms of KNPS licence NIL - 01 (Variation 19). It can be concluded that compliance with the RG-0011 guidelines for an NNPS will be achieved because of the periodic update of IKNEP to comply with NIL - 01 (Variation 19). The technical basis for IKNEP will include consideration of an NNPS.

### 9.1 General

1) Before final approval of a site, the feasibility of an emergency plan should be demonstrated. There should be no adverse site conditions which could hinder the sheltering or evacuation of the population in the region, or the ingress or egress of external services needed to deal with an emergency.

Comment: Feasibility of IKNEP has to be maintained for KNPS LTO and off-site EP response will envelop the limited response required for an NNPS when compared to that for KNPS.

2) For a nuclear licence to site, the emergency planning zones should be determined using site and facility design-specific information and the feasibility of an emergency plan should be demonstrated on the basis of site-specific natural and infrastructural conditions in the region. In this context, infrastructure means transport and communications networks, industrial activities and, in general, anything that may influence the rapid and free movement of people and vehicles in the region of the site. Other information on the region, such as information on the availability of sheltering, the systems for the collection and distribution of milk and other agricultural products, special population groups such as those residents in institutions (e.g. hospitals and prisons), industrial facilities, and environmental conditions such as the range of weather conditions, should be collected for demonstrating the feasibility of an emergency plan.

Comment: Feasibility of IKNEP has to be maintained for KNPS LTO and by means of IKNEP updates based on DSSR updates.

3)For a nuclear site licence, emergency planning zones must be identified and arrangements be in place for the controlling of developments in the vicinity, where appropriate, for the implementation of emergency measures. The emergency planning zones must be identified using enveloping source terms obtained from PSA studies for the scope of facility designs for which the application is made. See section 9.5 on reference accident (NNR, 2016a) and section 8.6 in this document.

Comment: IKNEP EPZ will be bounding for GEN III NPP. based on design certification information of RC frequencies for AP1000 and EPR when compared to those of KNPS. The information indicates significant lower RC frequencies that may result in off-site emergency response. PSA Level 3 studies will be updated during the next licensing phase when a specific GEN III NPP has been selected for the site. The results will be considered in the EPTB for IKNEP.

4) Many site-related factors should be taken into account in demonstrating the feasibility of an emergency plan. The most important factors are:

a) Population density and distribution in the region;

b) Distance of the site from population centres;

c) Special groups of the population that are difficult to evacuate or shelter, such as people in hospitals or prisons, or nomadic groups;

d) Particular geographical features such as islands, mountains and rivers;

e) Characteristics of local transport and communications networks;

f) Industrial facilities which may entail potentially hazardous activities;

g) Agricultural activities that are sensitive to possible discharges of radionuclides;

h) Possible concurrent external events.

**9.2 Roads and Infrastructure**

1) A site should be chosen with adequate roads, bridges, traffic control equipment and other facilities to support an orderly evacuation of identified populations.

2) Transportation facilities should be readily available to support evacuation of identified persons.

3) A qualitative assessment of the availability and quality of transportation infrastructure should be submitted.

**9.3 Evacuation Time Estimates**

1) Evacuation time estimate (ETE) calculations using conservative assumptions, qualified modellers and a generally accepted computer model should be submitted, with consideration to adverse weather and unusual situations.

**9.4 Coordination with Local Government**

1) It should be demonstrated that regional and local authorities have been contacted and that arrangements have been agreed to for the implementation of an emergency plan, if required.

2) An assessment of the capability of local authorities to support emergency response functions should be provided.

3) The submittal should include plans to compensate for any gaps in the ability of local authorities to support an emergency response.

**9.5 Reference Accident**

1) For a nuclear licence to site, all potential accidents should be identified and considered such as:

a) Events that could affect the facility or activity, including events of very low probability and events not considered in the design.

b) Events involving a combination of a nuclear or radiological emergency with a conventional emergency, such as an earthquake, a volcanic eruption, a tropical cyclone, severe weather, a tsunami, an aircraft crash or civil disturbances that may affect wide areas and/or impair capabilities to provide support in the emergency response.

c) Events that could affect several facilities and activities concurrently and the interactions among the facilities and activities affected.

2) Similarly, for an NISL the reference accident must be identified using PSA studies for the scope of facility designs for which the application is made.

3) For the purposes of the siting assessment, the consequences of a reference accident should be determined using enveloping assumptions. The reference accident selected should cover the set of accidents that can reasonably be foreseen in the safety analysis.

4) In calculating the effective dose to a population arising from the reference accident, no allowance should be made for the aversion of individual doses by means of short-term countermeasures such as sheltering, administration of stable iodine and evacuation.

5) The population considered when determining the effective dose should be the projected population for the lifetime of the facility including the temporary population.

6) The assumptions regarding meteorological conditions used in the dispersion calculation model should be demonstrated to be conservative with respect to the target parameter.

**9.6 Requirements and Criteria for Population and Emergency Planning Zones**

1) The emergency planning zones should include the following:

a) An exclusion zone (EZ);

b) An overall emergency planning zone (EPZ); and

c) A long-term protective action planning zone (LPZ).

2) In determining the emergency planning zones, the following criteria should be used in the definition of the required zones:

i) EZ – an effective dose (projected) of 100 mSv in the first seven days.

ii) LPZ – an effective dose (projected) of 100 mSv per annum.

iii) Overall EPZ – an effective dose (projected) of 1 mSv per annum.

3) The overall EPZ should include a low population zone considering arrangements for urgent protective actions such as iodine prophylaxis, for which an equivalent dose to the thyroid of 50 mSv (projected) should be used in the first seven days.

4) In the case of multiple nuclear facilities on the same site, the accident scenarios of the facilities that pose the highest impact should be used to derive the emergency planning zones. However in the consideration of external events, the integrated impact from all affected installations for a specific accident scenario should be considered. The emergency planning zones for the site may have to be modified should the existing zoning scheme be compromised as a result of the new nuclear installation’s source term.

5) In addition to the determination of the boundaries of the three emergency planning zones, radii should be specified for all protective actions and low population zone areas.

6) An exclusion area should be determined where the applicant has the authority to determine all activities within that area, including the removal of personnel and property.

**9.7 Developments Around Nuclear Sites**

1) In the case of a nuclear licence to site a nuclear facility, the NNR will direct the holder in terms of section 38(1) of the NNR Act to enter into an agreement with the relevant municipalities and provincial authorities to establish an emergency plan within a period determined by the Regulator. In terms of section 38(4) of the NNR Act the NNR will propose regulations for promulgation by the Minister on the development surrounding any nuclear facility to ensure the effective implementation of any applicable emergency plan.

 

2) In the case of an NSL the validity of the proposed emergency planning zones and measures to control development should be reassessed periodically.

3) The applicant as well as municipal and provincial authorities should ensure adequate infrastructure as per their legislated mandates and/or cooperative governance agreements as may be necessary for the effective implementation of the emergency plan.

4) Within the low population zone, arrangements should be in place for other urgent protective actions such as iodine prophylaxis. Contingency arrangements should be in place for the sheltering and evacuation of the public in the low population zone.

5) Within the low population zone, compliance with the evacuation time criteria should be demonstrated by the municipal authority by means of a TEM.

6) Any increase in the population in the low population zone should be controlled in terms of the regulations on the control of development for the site issued in accordance with Section 38(4) of the NNR Act.

## Appendix 8-B: Examples of GEN III NPPS considered by Eskom

### Table A8- 1: Comparison of Key Characteristics of GEN III NPS (extracted from DSSR Chapter 3)

| Characteristic | KNPS (reference) | AP 1000 | APR1400 | EPR | VVER1000 |
|---|---|---|---|---|---|
| Developer | Framatome | Westinghouse/ Mitsubishi | Dosam (KNPH) | Framatome | Rosatom (ASE) |
| Core thermal power (MWt) | 2 775 | 3 400 | 3 983 | 4 250 | 3 200 |
| NSS thermal power (MWt) | 2 790 | 3 415 | 4 000 | 4 500 | 3 212 |
| Net electrical power output (MWt) | 900 | 1 117 | 1 400 | 1 600-1 700 | 1 082 |
| Plant efficiency (%) | 32 | 35.6 | 35 | 37 | 34.5 |
| Plant design life (years) | 40 | 60 | 60 | 60 | 60 |
| No of loops | 3 | 2 hot legs/ 4 cold legs | 4 | 4 | 4 |
| Fuel assembly pin array | 17x17 | 17x17 square | 16x16 square | 17x17 square | Hexagonal |
| No of fuel assemblies per core | 157 | 157 | 241 | 241 | 163 |
| Enrichment limits (%) | 4.95 | 4.80 | 3.80 | 5 or MOX (mixed Oxide Fuel) | 4.69 |
| No of steam generators per reactor | 3 | 2 with triangular pitch | 2 with triangular pitch | 4 | 4 corridor arrangement |
| Layout of steam generators | Vertical | Vertical | Vertical | Vertical | Horizontal |
| Reactor coolant pumps | 3 | 4 | 4 | 4 | 4 |

## Appendix 8-C: NNR PP-0015 EP Criteria

The basis of NNR PP-0015 is IAEA GSR Part 7 (IAEA, 2015). The content of the following are as they appear in GSR Part 7.

**Table A8-2: Generic criteria for doses received within a short period of time for which protective actions and other response actions are expected to be taken under any circumstances in a nuclear or radiological emergency to avoid or to minimize severe deterministic effects.**

| | | |
|---|---|---|
| **Acute external exposure (<10 h)** | | |
| $AD_{\text{red marrow}}$ [a] | 1 Gy | If the dose is projected:<br>— Take precautionary urgent protective actions immediately (even under difficult conditions) to keep doses below the generic criteria;<br>— Provide public information and warnings;<br>— Carry out urgent decontamination. |
| $AD_{\text{fetus}}$ | 0.1[b] Gy | |
| $AD_{\text{tissue}}$ [c] | 25 Gy at 0.5 cm | |
| $AD_{\text{skin}}$ [d] | 10 Gy to 100 $cm^2$ | |
| **Acute internal exposure due to an acute intake ($\Delta$ = 30 d[e])** | | |
| $AD(\Delta)_{\text{red marrow}}$ | 0.2 Gy for radionuclides with atomic number $Z \geq 90$[f]<br>2 Gy for radionuclides with atomic number $Z \leq 89$[f] | If the dose has been received:<br>— Perform immediate medical examination, medical consultation and indicated medical treatment;<br>— Carry out contamination control;<br>— Carry out immediate decorporation[g] (if applicable);<br>— Conduct registration for longer term medical follow-up;<br>— Provide comprehensive psychological counselling. |
| $AD(\Delta)_{\text{thyroid}}$ | 2 Gy | |
| $AD(\Delta)_{\text{lung}}$ [h] | 30 Gy | |
| $AD(\Delta)_{\text{colon}}$ | 20 Gy | |
| $AD(\Delta')_{\text{fetus}}$ [i] | 0.1[b] Gy | |

a) $AD_{\text{red marrow}}$ represents the average relative biological effectiveness (RBE) weighted absorbed dose to internal tissues or organs (e.g. red marrow, lung, small intestine, gonads, thyroid) and to the lens of the eye from exposure in a uniform field of strongly penetrating radiation.

b) At 0.1 Gy there would be only a very small probability of severe deterministic effects to the foetus and only during certain periods post-conception (e.g. between 8 and 15 weeks of in utero development), and only if the dose is received at high dose rates. During other periods post-conception and for lower dose rates, the foetus is less sensitive. There is a high probability of severe deterministic effects at 1 Gy.

 

Therefore, 1 Gy is used as the generic criterion for doses to the foetus received within a short period of time: (i) in the hazard assessment, to identify facilities and activities, on-site areas, off-site areas and locations for which a nuclear or radiological emergency could warrant precautionary urgent protective actions to avoid or to minimize severe deterministic effects; (ii) for identifying situations in which exposure is dangerous to health; and (iii) for making arrangements for applying decisions on urgent protective actions and other response actions to be taken off the site to avoid or to minimize the occurrence of severe deterministic effects (e.g. establishing a precautionary action zone).

c) Dose delivered to 100 $cm^2$ at a depth of 0.5 cm under the body surface in tissue due to close contact with a radioactive source (e.g. source carried in the hand or pocket).

d) The dose is to the 100 $cm^2$ dermis (skin structures at a depth of 40 $mg/cm^2$ (or 0.4 mm) below the surface).

e) AD(Δ) is the RBE weighted absorbed dose delivered over a period of time Δ by the intake (I05) that will result in a severe deterministic effect in 5% of exposed individuals.

f) Different generic criteria are used to take account of the significant difference in RBE weighted absorbed dose from exposure at the intake threshold values specific for these two groups of radionuclides.

g) Decorporation is the action of the biological processes, facilitated by chemical or biological agents, by means of which incorporated radionuclides are removed from the human body. The generic criterion for decorporation is based on the projected dose without decorporation.

h) For the purposes of these generic criteria, ‘lung’ means the alveolar–interstitial region of the respiratory tract.

i) For this particular case, AD(Δ’) refers to the period of in utero development of the embryo and foetus.

 

**Table A8-3: Generic criteria for taking protective actions and other response actions in a nuclear or radiological emergency to reduce the risk of stochastic effects.**

| Generic criteria | | Examples of protective actions and other response actions[a] |
|---|---|---|
| **Projected dose that exceeds the following generic criteria: Take urgent protective actions and other response actions** | | |
| $H_{thyroid}$ | 50 mSv[b] in the first 7 days | Iodine thyroid blocking[c] |
| $E^{d}$ | 100 mSv in the first 7 days | Sheltering[e]; evacuation; prevention of inadvertent ingestion; restrictions on food, milk and drinking water[g] and restrictions on the food chain and water supply; restrictions on commodities other than food; contamination control; decontamination; registration; reassurance of the public |
| $H_{fetus}{}^{f}$ | 100 mSv in the first 7 days | |
| **Projected dose that exceeds the following generic criteria: Take early protective actions and other response actions** | | |
| $E^{d}$ | 100 mSv in the first year | Temporary relocation; prevention of inadvertent ingestion; restrictions on food, milk and drinking water[g] and restrictions on the food chain and water supply; restrictions on commodities other than food; contamination control; decontamination; registration; reassurance of the public |
| $H_{fetus}{}^{f}$ | 100 mSv for the full period of in utero development | |

a) These examples are neither exhaustive nor grouped in a mutually exclusive way.

b) The equivalent dose to the thyroid ($H_{thyroid}$) only due to exposure to radioiodine.

c) This generic criterion applies only for administration of iodine thyroid blocking. For the thyroid, iodine thyroid blocking is an urgent protective action that is prescribed: (a) if exposure due to radioactive iodine is involved, (b) before or shortly after a release of radioactive iodine, and (c) within only a short period before or after the intake of radioactive iodine.

d) Effective dose.

e) As a less disruptive protective action, sheltering may be ordered at lower doses as long as justified and optimized as specified in IAEA GSR Part 7.

f) $H_{fetus}$ is the equivalent dose to the foetus, derived as the sum of the dose from external exposure and the maximum committed equivalent dose to any organ of the embryo or foetus from intake to the embryo or foetus for different chemical compounds and different times relative to conception.

 

g) Restrictions on food, milk and drinking water using these generic criteria are to be applied before sampling and analysis of food, milk and drinking water are carried out. Such restrictions apply as long as replacements of food, milk and drinking water or other alternatives are available to ensure they would not result in severe malnutrition, dehydration or other severe health impacts.

h) When results of the health screening indicate that the criteria in ***Table A8-3*** are exceeded, then appropriate medical attention is necessary as referred to in IAEA GSR Part 7.

 

## Appendix 8-D: The Enhanced Design Safety of a GEN III NPP

GEN III NPPs aim to eliminate the need for intervention in public domain through the use of enhanced passive safety features in their design. Many of these designs also aim to take advantage of the advanced safety characteristics to seek exemption from maintaining a large exclusion distance around the nuclear power plants. The confinement function for GEN III NPPs is strengthened (IAEA, 2006). It must be demonstrated, by deterministic and probabilistic means, that hypothetical severe accident sequences that could lead to large radioactive releases due to early containment failure are essentially eliminated with a high degree of confidence.

Earlier NPP construction safety assessments such as KNPS included beyond design basis accidents (BDBA), accidents postulated to occur less frequently than a design basis accident (DBA); typically less frequent than 1E-06/y. GEN III design safety includes the concept of design extension conditions from the outset. The IAEA defines requirement in terms of design extension conditions as follows (IAEA, 2012):

A set of design extension conditions are derived on the basis of engineering judgement, deterministic assessments and probabilistic assessments for the purpose of further improving the safety of the NPP by enhancing the plant's capabilities to withstand, without unacceptable radiological consequences, accidents that are either more severe than design basis accidents or that involve additional failures. These design extension conditions are used to identify the additional accident scenarios to be addressed in the design and to plan practicable provisions for the prevention of such accidents or mitigation of their consequences if they do occur.'

The changes are illustrated in ***Table A8-4*** and show the different NNP conditions, progressing from normal operation to BDBAs. The concepts illustrated in Table A8-4 are briefly discussed.

### Table A8-4: A Comparison of GEN II and GEN III Safety Requirements

<table>
<tr><td colspan="6">2000: IAEA Safety Requirements publication on Safety of Nuclear Power Plants: Design -Safety Standards Series No. NS-R-1</td></tr>
<tr><td colspan="2">Operational States</td><td colspan="4">Accident Conditions</td></tr>
<tr><td>Normal Operation</td><td>Anticipated Operational Occurrence</td><td>Design Basis Accidents</td><td colspan="3">Beyond Design Basis Accidents</td></tr>
<tr><td colspan="3"></td><td></td><td>Severe Accidents</td><td></td></tr>
<tr><td colspan="3">Included in the design basis</td><td colspan="3">Beyond Design Basis Accidents</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td colspan="6">2012: IAEA Safety Standards Series No. SSR-2/1 Safety of Nuclear Power Plants Design: Specific Safety Requirements</td></tr>
<tr><td colspan="2">Operational States</td><td colspan="4">Accident Conditions</td></tr>
<tr><td>Normal Operation</td><td>Anticipated Operational Occurrence</td><td>Design Basis Accidents</td><td colspan="2">Design Extension Conditions</td><td rowspan="2">Conditions Practically Eliminated</td></tr>
<tr><td colspan="3"></td><td>No Reactor Core Melt</td><td>Severe Accidents - Reactor Core Melt</td></tr>
<tr><td colspan="5">Included in the design basis</td><td>Beyond Design Basis Accidents</td></tr>
</table>

 

These additional safety features for design extension conditions, or this extension of the capability of safety systems, must ensure the capability for managing accident conditions in which there is a significant amount of radioactive material in the containment (including radioactive material resulting from severe degradation of the reactor core). A GEN III NPP has design criteria so that it can be brought into a controlled state and the containment function can be maintained. The design is such that design extension conditions that could lead to significant radioactive releases are practically eliminated. If not, for design extension conditions that cannot be practically eliminated, only protective measures that are of limited scope in terms of area and time shall be necessary for protection of the public, and sufficient time shall be made available to implement these measures. GEN III NPPs have distinctive characteristics in respect of design extension conditions. These include (J.G., 2010):

- simpler designs making the reactors easier to operate and more tolerable of abnormal operating conditions;
- passive safety features in the design of the structures, systems, and components (SCCs) that avoid use of active control and relying on natural phenomena such as natural circulation of cooling media, e.g. cooling of the containment building to avoid overpressure;
- reduced probabilities for the failure of SCCs and a lower reactor core damage frequency (CDF) compared to earlier generation reactors (an order of magnitude reduction);
- new design features that provide mitigation to reduce the release of radioactivity to the environment significantly should the reactor core melt;
- improved resistance to external hazards such as aircraft crash and extreme natural events.