NATIONAL NUCLEAR REGULATOR

For the protection of persons, property and the environment against nuclear damage

POSITION PAPER

EMERGENCY PLANNING TECHNICAL BASIS FOR NEW NUCLEAR INSTALLATIONS

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1. BACKGROUND

The fundamental safety objective, as per the NNR Act [1], is to protect persons, property and the environment from the harmful effects of ionizing radiation.

The IAEA [2] specifies in principles 9 and 10 that arrangements must be made for emergency preparedness and response for nuclear or radiation incidents, and that protective actions to reduce existing or unregulated radiation risks must be justified and optimized.

In designing a nuclear installation a comprehensive safety analysis is carried out to identify all sources of exposure and to evaluate radiation doses associated with the facility. This analysis includes the identification of accident scenarios upon which emergency planning zones and associated arrangements for emergency preparedness and response are established. The sizes of the emergency planning zones are usually determined on the basis of radionuclide release and dispersal calculations for a selected set of postulated accidents.

Emergency planning is an activity of incorporating into an emergency plan, a system of measures for preventing deterministic effects and mitigating stochastic effects of the consequences of an accident and for creating and maintaining of emergency preparedness. Emergency plans for nuclear installations are developed from the concept of intervention to reduce public exposure in the event of an accident.

2. PURPOSE

The purpose of this document is to specify, for new nuclear installations, the regulatory position for the development of a technical basis for emergency planning zones which shall be based on the analysis of potential accident scenarios and consequences which could potentially impact on workers, public and the environment.

3. REFERENCES

The following documents were consulted during the compilation of this document:

[1] National Nuclear Regulator Act, 47 of 1999

[2] SF-1, Fundamental Safety Principles, IAEA, 2006

[3] The Regulations on Licensing of Sites for New Nuclear Installations, Government Notice R927, 11 November 2011

[4] GSR Part 3, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, Interim Edition, IAEA, 2011

[5] Safety Series No 115, International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, IAEA, 1996

[6] GS-R-2, Preparedness and Response for a Nuclear or Radiological Emergency, IAEA, 2002 (under review)

[7] GSG-2, Criteria for Use in Preparedness and Response for a Nuclear or Radiological Emergency, IAEA, 2011

[8] RD-014, Emergency Preparedness and Response Requirements for Nuclear Installations, 2005

[9] JRC Scientific and Technical Reports, Risk Informed Support Decision Making for Nuclear Power Plant Emergency Zoning, EUR 23280 EN, 2008

[10] RD-0016, Requirements for authorisation submissions involving computer software and evaluation models for safety calculations, 2006

[11] The NNR Report on the Technical Basis for Emergency planning at the Koeberg Nuclear Power Station, 2000

[12] EPR-METHOD-2003, Method for Developing Arrangements for Response to a Nuclear of Radiological Emergency, IAEA, 2003

[13] European Utility Requirements for LWR Nuclear Power Plants, Copyright British Energy et al., 1999 - 2002.

[14] RD-034, Quality and Safety Requirements for Nuclear Installations, 2008

[15] ICRP Publication 109, Application of the Commission's Recommendations for the Protection of People in Emergency Exposure Situations, 2009

4. TERMS, DEFINITIONS AND ABBREVIATIONS

4.1 Terms & Definitions

avertable dose: The dose that could be averted if a countermeasure or set of countermeasures were to be applied.

credible accident: an accident that could be expected to occur once in a million years (has a probability of 10^{-6} per year).

deterministic safety analysis: Analysis using, for key parameters, single numerical values (taken to have a probability of 1), leading to a single value of the result, performed under specific predetermined assumptions concerning the initial operational state and the initiating event, with specific sets of rules and acceptance criteria.

emergency exposure: Exposure received in an emergency. This may include unplanned exposures resulting directly from the emergency and planned exposures to persons undertaking actions to mitigate the consequences of the emergency. Emergency exposure may be occupational exposure or public exposure.

model validation: The process of determining whether a model is an adequate representation of the real system being modelled, by comparing the predictions of the model with observations of the real system.

model verification: The process of determining whether a computational model correctly implements the intended conceptual model or mathematical model.

Operational Intervention Level (OIL): A calculated level, measured by instruments or determined by laboratory analysis, that corresponds to an intervention level or action level.

probabilistic safety assessment (PSA): A comprehensive structured approach to identifying failure scenarios, constituting a conceptual and mathematical tool for deriving numerical estimates of risk. Three levels of PSA are generally recognized.

projected dose: The dose that would be expected to be received if planned protective actions were not taken.

Relative Biological Effectiveness (RBE): A measure of the relative effectiveness of different radiation types at inducing a specified health effect, expressed as the inverse ratio of the absorbed doses of two different radiation types that would produce the same degree of a defined biological end point.

reference level: The level of dose, risk or activity concentration above which it is not appropriate to plan to allow exposures to occur and below which optimization of protection and safety would continue to be implemented.

residual dose: the dose expected to be incurred in the future after protective actions have been terminated (or a decision has been taken not to implement protective actions).

source term: The amount and isotopic composition of material released (or postulated to be released) from a facility.

hazard assessment: the process of analysing systematically the hazards associated with facilities, activities or sources in order to identify those events and the associated areas for which protective actions may be required.

4.2 Abbreviations

BDBA	:	Beyond Design Basis Accident
CSAU	:	Code Scaling Applicability and Uncertainty
ECD	:	Effective Committed Dose
EMDAP	:	Evaluation Model Development and Assessment Process
EP	:	Emergency Planning
EPZ	:	Emergency Planning Zone(s)
EUR	:	European Utility Requirements
EZ	:	Exclusion Zone
IAEA	:	International Atomic Energy Agency
ICRP	:	International Commission on Radiation Protection
JRC	:	Joint Research Centre (European Commission)
LER	:	Large Early Release
LLR	:	Large Late Release
LPZ	:	Long Term Protective Action Planning Zone
NI	:	Nuclear Installation
NNR	:	National Nuclear Regulator
NPP	:	Nuclear Power Plant
OIL	:	Operational Intervention Level
PAZ	:	Precautionary Action Zone
PSA	:	Probabilistic Safety Assessment
PWR	:	Pressurized Water Reactor
SOARCA	:	State-of-The-Art Reactor Consequence Analyses
SPAR	:	Standardized Plant Analysis Risk
UPZ	:	Urgent Protective Planning Zone

5. APPROACHES TO EMERGENCY PLANNING TECHNICAL BASIS

5.1 International approaches and practices

The determination of EPZ's and drawing up of emergency plans vary from country to country. Usually in emergency planning for Nuclear Installations, simplified deterministic approaches are used where a reference accident is defined for use as a basis for drawing up corresponding emergency plans.

A number of countries use the outputs from PSA Level 2 and 3 analysis to estimate the offsite consequences of beyond design basis accidents (BDBA) and severe accidents of Nuclear Installations. This approach is used to provide an acceptable basis for implementation of risk informed support in decision making processes, especially in defining emergency zones around Nuclear Installation sites (see Appendix 1).

5.2 Calculation Methodology

Calculation methodologies involving the determination of doses, via the relevant exposure pathways, are typically used for estimating/predicting areas where criteria for emergency actions are reached following the release of radioactive material. The methodologies typically entail the following steps:

1. Estimation of source terms for each of the accidents considered to be relevant for off-site emergency planning for the site.
2. Calculation of the projected off-site doses arising from the accident source terms based on site-specific or generic information on meteorology, population, etc. The calculations may be repeated to reflect the proposed countermeasures in order to determine avertable dose.
3. Determination of the protective action radii required to satisfy the criteria for evacuation, sheltering and iodine distribution, using the doses obtained from step 2, in conjunction with the corresponding accident frequencies determined in the PSA. Uncertainties in the dose and frequency calculations should be taken into account.
4. Optimisation of the emergency planning zone boundaries taking into account the practicability of implementing the protective action, e.g. transport, evacuation plans, timing for implementing the actions, and natural geographical or administrative boundaries.

5.3 National approaches and practices

The NNR adopts an approach where both the deterministic analysis of the potential consequences of accidents and the analysis of the risk related to the entire spectrum of potential accidents are utilized. The deterministic analysis is used in the evaluation of accident scenarios taking into consideration the consequences of potential severe accidents for various weather patterns whereas risk insights from the Probabilistic Safety Analysis (PSA) are used to determine the Reference Accident/s. The PSA takes into account the risk to members of the population that is obtained through a systematic analysis of the external events, plant behaviour, plant vulnerabilities, accident progressions, and radioactive release dispersion models in the environment and the consequential doses to the members of the public. This analysis considers amongst others failure frequencies of equipment, behaviour of radioactive release inside and outside the containment and the impact of meteorology data on the dispersion of these radioactive releases products.

6. EMERGENCY PLANNING REQUIREMENTS

Internationally accepted fundamental principles and requirements are set out in documents published by the ICRP and the IAEA. The IAEA safety standards prescribe generic dose criteria for intervention, together with generic guidance on the size of emergency planning zones and protective actions to be implemented within them.

Various countries have implemented different approaches, methodologies and criteria for determining emergency planning zones. A review of best practises in defining emergency planning zones and how requirements and associated criteria are implemented is included in Appendix 1.

6.1 International Atomic Energy Agency

6.1.1 Threat Assessment

The IAEA recommends that the nature and extent of emergency arrangements for preparedness and response shall be commensurate with the potential magnitude and nature of the threat associated with the facility or activity. The full range of postulated events shall be considered in the threat assessment. In the threat assessment any populations at risk shall be identified and, to the extent practicable, the likelihood, nature and magnitude of the various radiation related threats shall be considered. The threat assessment shall be so conducted as to provide a basis for establishing detailed requirements for arrangements for preparedness and response by categorizing facilities and practices consistent with the IAEA categories as defined in IAEA Safety Standards [6, 12].

The IAEA defines the threat categories I, II and III for nuclear installations as follows:

“Threat category I - facilities such as nuclear power plants, for which on-site events (including very low probability events) are postulated that could give rise to severe deterministic health effects off the site, or for which such events have occurred in similar facilities.”

“Threat category II - facilities such as some types of research reactors, for which on site events are postulated that could give rise to doses to people off the site that warrant urgent protective action in accordance with international standards, or for which such events have occurred in similar facilities.”

“Threat category III - facilities, such as industrial irradiation facilities, for which on-site events are postulated that could give rise to doses that warrant or contamination that warrants urgent protective action on the site, or for which such events have occurred in similar facilities. Threat category III (as opposed to threat category II) does not include facilities for which events are postulated that could warrant urgent protective action off the site, or for which such events have occurred in similar facilties".

6.1.2 Countermeasures

In a threat assessment, facilities, sources, practices, on-site areas, off-site areas and locations shall be identified for which a potential nuclear or radiological emergency could warrant:

- Precautionary urgent protective action to prevent severe deterministic health effects by keeping doses below those for which intervention would be necessary to undertake under any circumstances;
- Urgent protective action to prevent stochastic effects to the extent practicable by averting doses, in accordance with international standards;
- Agricultural countermeasures, countermeasures to ingestion and longer term protective measures, in accordance with international standards; or
- Protection for the workers responding (undertaking an intervention) to the emergency, in accordance with international standards.

6.1.3 Protection Strategy

The IAEA recommends [4] that the government shall ensure that protection strategies are developed, justified, and optimized at the planning stage, by using scenarios based on the hazard assessment, for avoiding deterministic effects and reducing the likelihood of stochastic effects due to public exposure. A protection strategy, comprising specific protective actions and other response actions, shall include, but shall not be limited to, the following steps:

- A reference level expressed in terms of residual dose shall be set, typically an effective dose in the range 20–100 mSv that includes dose contributions via all exposure pathways. The protection strategy shall include planning for residual doses to be as low as reasonably achievable below the reference level, and the strategy shall be optimized.
- On the basis of the outcome of the optimization of the protection strategy, using the reference level, generic criteria for particular protective actions and other actions, expressed in terms of projected dose or dose that has been received, shall be developed. If the numerical values of the generic criteria are exceeded, those protective actions and other actions, either individually or in combination, shall be implemented.
- Once the protection strategy has been optimized and a set of generic criteria has been developed, pre-established default triggers for initiating the different parts of an emergency plan, primarily for the initial phase, shall be derived from the generic criteria. Default triggers, such as on-scene conditions, operational intervention levels and emergency action levels, shall be expressed in terms of parameters or observable conditions. Arrangements shall be established in advance to revise these triggers, as appropriate, in an emergency exposure situation, with account taken of the prevailing conditions as these evolve.

6.1.4 Emergency Planning Zones

Off-site emergency planning zones shall be specified for which arrangements shall be made for taking urgent protective action [6]. The emergency planning zones shall be contiguous across national borders, where appropriate, and shall include:

- A precautionary action zone (PAZ), for facilities in threat category I, for which arrangements shall be made with the goal of taking precautionary urgent protective action, before a release of radioactive material occurs or shortly after a release of radioactive material begins, on the basis of conditions at the facility (such as the emergency classification) in order to reduce substantially the risk of severe deterministic health effects.
- An urgent protective action planning zone (UPZ), for facilities in threat category I or II, for which arrangements shall be made for urgent protective action to be taken promptly, in order to avert doses off the site in accordance with international standards.

In [12] a Food Restriction Planning Radius is described as the area where preparations for effective implementation of protective actions to reduce the risk of stochastic health effects from the ingestion of locally grown food should be developed in advance. In general, protective actions such as relocation, food restrictions and agricultural countermeasures will be based on environmental monitoring and food sampling.

6.2 European Utility Requirements

The EUR focuses on ensuring that the risk from new NPP’s in terms of large off-site releases of radioactivity would be very much lower than that for the current plants. Four goals were defined to substantiate the notion of limited impact in case of severe accidents [9, 13]:

- No emergency protection action is needed beyond the site boundary, i.e. beyond 800 metres from the reactor. This means that the averted Effective Committed Dose (ECD) over a period of 7 days, following accident initiation, will remain below 50 mSv, which is the generic intervention value (as per ICRP No. 63) and which was adopted in the IAEA Basic Safety Series No. 115. Practically speaking, evacuation and sheltering of people are not needed for such low values.
- No delayed action is needed beyond 3 km from the reactor. This means that the averted ECD over a period of thirty consecutive days following the release termination remains below 30 mSv. This assures that the temporary relocation intervention level reported in the IAEA Basic Safety Series No. 115 is not reached.
- No long term action is required beyond site boundary. This means that the averted ECD over a period of fifty years following release termination remains below 100 mSv. This limit is lower than that recommended in the IAEA Basic Safety Standards No. 115, but it is considered consistent with the two above mentioned criteria by the EUR group.

- Limited economical impact linked to the restriction of foodstuff consumption. This means allowing free trading of foodstuffs, provided a 5 mSv dose to individuals eating contaminated food for one year is not reached:
  - after one month following the end of the accident over a 30 km square area;
  - after one year following the end of the accident over a 10 km square area.

This means that foodstuffs produced in areas of 30 km square and 10 km square surrounding the site could be marketed after one month and one year respectively..

The four goals defined to substantiate the notion of limited impact in case of severe accidents are associated with a probabilistic safety target [13] which requires that "the cumulative frequency of exceeding the 4 criteria for limiting impact shall be lower than 1E-6 per reactor year.

6.3 South African National requirements

6.3.1 Siting Regulation R927

The identification and determination of emergency planning zones use the characteristics of the site, source term analysis, design information, radiological impact analysis as well as risk insights. The emergency planning zones must include the following:

- An exclusion zone (EZ) which is a radius determined for the purposes of evacuating persons in the event of a nuclear accident. Within the boundaries of that zone or within any erven intersecting with that zone there must be no members of the public resident, no uncontrolled recreational activities, no commercial activities, or institutions which are not directly linked to the operation of nuclear installations situated within this zone, or for which an authorization has not been been granted;
- An overall Emergency Planning Zone (EPZ) of such size that emergency or remedial measures must be considered where the potential exists that any members of the public may receive more than an annual effective dose of 1 mSv due to the source term;
- A Long Term Protective Action Planning Zone (LPZ), where preparations for effective implementation of protective actions to reduce the risk of stochastic health effects from long term exposure to deposition and ingestion must be developed in advance, consistent with international standards.

6.3.2 RD-014

Emergency preparedness and response requirements for currently licensed nuclear installations in South Africa are detailed in RD-014 "Emergency Preparedness and Response Requirements for Nuclear Installations, Rev.0, 2005 and are broadly consistent with the IAEA Safety Standards.

RD-014 requires consideration of a threat assessment, establishment of emergency planning zones, determination of potential protective actions, and compliance with intervention criteria. RD-014, consistent with the IAEA Safety standards, defines the following emergency planning zones, within which detailed arrangements are required to be developed for implementation of protective actions are:

- Precautionary Action Zone (PAZ) – where the risk of deterministic effects is sufficiently high to warrant pre-emptive protective actions based on plant conditions, before or shortly after any release of radioactivity to the environment.
- Urgent Protective Action Zone (UPZ) – where the risk of stochastic effects is sufficiently high to warrant plans to implement protective actions based on environmental monitoring or plant conditions.
- Long term Protective Action Planning 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 are developed in advance.

7. REGULATORY POSITION

Emergency Planning Zones represent areas in which planning for given protective actions must take place. The zones, as well as the required actions in the respective zones, are to be based on the consequences due to possible accidents which should be determined from a hazard assessment and a plant-specific risk analysis where relevant.

If alternative approach and/or criteria are adopted to define the Emergency Planning Zones, they should be justified and agreed with the Regulator on a case by case basis.

All documents, data, processes and systems used in the development of the Emergency Planning Technical Basis should comply with regulatory quality management requirements [14].

7.1 Protection Strategy

The protection strategy, comprising specific protective actions and other response actions, to be developed and justified by the applicant/authorization holders should include, but not be limited to:

- *A reference level (effective dose) of 50 mSv, expressed in terms of residual dose, which includes dose contributions via all exposure pathways.*
- *Generic criteria for implementing precautionary and urgent protective actions to prevent severe deterministic effects expressed in terms of projected dose.*
- *Generic criteria for implementing urgent protective and other response actions to reduce the risk of stochastic effects.*

The protection strategy should be optimized to reduce exposures below the reference level. For accidents of a lasting nature and the exposure circumstances, the pre-selected reference level against which to assess the optimisation of protection is expressed as an annual dose. For accidents involving no long term environmental contamination, the preselected reference level is the dose received as a result of the accident. A process of optimisation should be used to determine what total residual dose(s) will be acceptable in particular circumstances. The concept of averted dose should be used for the assessment of the efficiency of individual protective actions or their combination.

7.2 Emergency Planning Zones

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

- *Effective dose (projected) of 100 mSv over in 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 3.
Criteria for protective actions to avoid or mimimise severe deterministic effects, and to reduce the risk of stochastic effects, for the determination of Emergency Planning Zones are included in Appendices 3 and 4.

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. 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 source term.

In addition to the determination of the boundaries of the three emergency planning zones, radii should be specified for all protective actions required in accordance with the criteria above and in the Appendices.

7.3 Calculation Methodology

The accident analysis methodology to be employed by the holder or applicant for the establishment of the emergency planning technical basis should consist of the following steps (see Figure 1):

***Step 1**: Selection of representative accident scenarios*
This selection should address a range of accident conditions that can reasonably be foreseen from the safety analysis. Consideration should be given to:

- *a range of event probabilities and consequences, sufficient to adequately assess the total risk from the installation.*
- *not only major accidents with long pre-release phases, but also more frequent accidents which may produce a sudden small release without any pre-warning, as timing of the environmental release is important when responding to accidents.*
- *the worst credible accident in order to stay aware of possible consequences in very rare situations.*
- *additional scenarios that may be identified as a result of accidents at similar installations.*

The Reference Accident using regulatory criteria should be defined upon which emergency planning zones and their associated protective actions are based. The term Reference Accident is usually applied to one of a selected set of accidents that can reasonably be foreseen in the safety analysis. It is representative of the particular risk associated with a particular establishment and which operators and competent authorities may use to guide their prevention and emergency preparation strategies. In practise, it may be better to consider a range of accident conditions that is truly representative of the risk posed by the establishment from which the protective actions, timescales for implementation thereof should be determined.

***Step 2**: Source Terms*
Estimation of source terms for the representative accident scenarios, including information on release composition and chemical form, release point and plume height. This should be consistent with the parameters used in the safety analysis to ensure consistency in approach.

***Step 3**: Meteorological data*
The meteorological sequences should be grouped into a number of categories to cater for comparable radiological consequences for a given release, and that adequate resolution is provided over the whole spectrum of consequences that result from the distribution of meteorological conditions.

***Step 4**: Atmospheric Dispersion and Deposition*
Radionuclides released to the atmosphere will create a plume that is carried downwind. As the plume is carried downwind, transport and diffusion profiles should be considered. The concentration profiles (crosswind and vertical) of the dispersing plume should be defined for the consequence assessment.

***Step 5**: Dose calculations*
Performance of dose calculation and determination of protective action radii, for each source term. This should include:

- *Calculation, for each source term, of the projected dose as a function of distance from the release point. This should consider site specific parameters, i.e. meteorology, building layout, etc. as well as all the exposure pathways and duration of exposure.*
- *Comparison with generic dose criteria, to determine the preliminary protective action radii. Timing of interventions relative to time and duration of the release should also be considered. In this case credit can be taken for occupancy patterns, shielding factors, thyroid dose reduction factors, etc. Credit for protective actions should only be taken where the timing of intervention is realistic.*

The optimisation of the effectiveness of the overall strategy should be included in the emergency plan. This should be an iterative process, involving all stakeholders, and robust for a range of circumstances in which the proposed component protective measures are optimised and then their contribution to the overall strategy assessed and optimised.

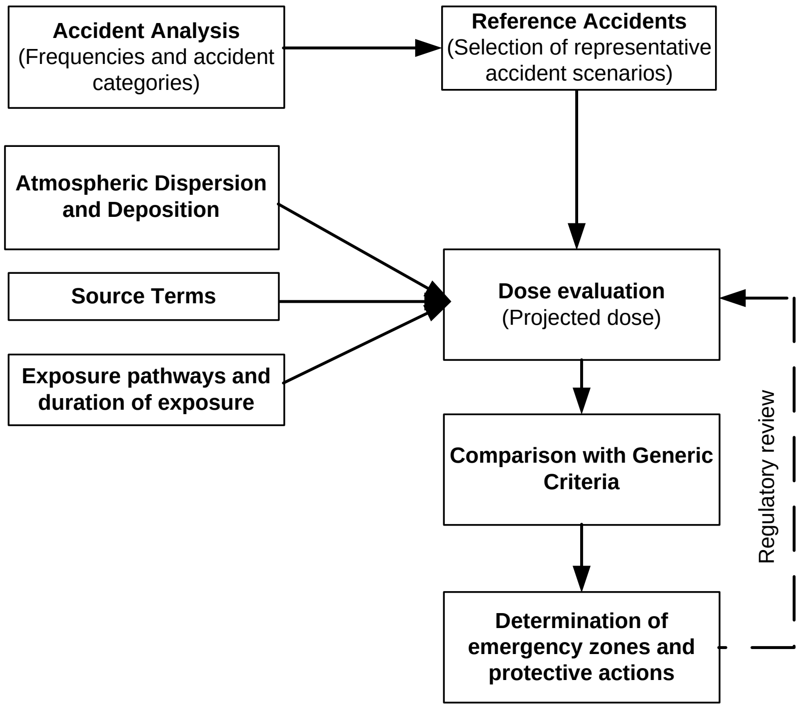


Figure 1: Dose calculation methodology

7.3.1 Accident Selection Methodology

The size of the Exclusion Zone should be such that it is not credible that evacuation of the public would be needed outside of this zone. Based on the analysis of the accident scenarios and their respective frequencies the likelihood of exceeding the evacuation dose criteria at any distance from the plant is determined.
A graph should be drawn of the likelihood (F) of exceeding the generic criteria for evacuation to prevent stochastic effects at any distance (R) from the plant. (see Appendix 2)

The graph will always decrease with larger radius R as the likelihood for exceeding any particular dose will get smaller at larger distances. Conceptually, the value of R at which the "threshold" of 10^{-6} pa is reached represents the desired radii associated with protective action criteria.

7.3.2 Dose Assessment Factors

7.3.2.1 Source Term

The starting point for a consequence dose assessment is the postulated radionuclide releases to the environment from the hazard assessment process.

The information on the radionuclide releases to the atmosphere is provided for each of the representative accidents to be assessed, obtained by grouping accidents with similar release characteristics together. The range of source terms for the representative accidents is referred to as the ‘accident source term spectrum’.

A detailed hazard assessment is to be performed, which should consider a range of all potential accidents and may involve a PSA.

The Source Term should specify both the time dependent magnitude of the release (i.e. the quantity of each radionuclide released to the atmosphere as a function of time) and, by defining a number of release parameters, the manner of the release. These release parameters should include the time of the release after accident initiation, the duration of the release, the amount of energy associated with the release, the height of release and the predicted frequency of occurrence of the accident.

In principle, to fully define the source term, information on the physical properties and chemical form including the particle size should be included. The specific nuclides and associated release fractions should be specified together with the activity concentration of each nuclide released.

A PSA to derive the Source Terms should comply with international standards, and should be justified for use to the Regulator. A justification should be provided for the definition of plant damage end states. A justification should be provided on the radionuclide binning schemes used for the definition of plant damage end states. Accident progressions that are grouped into a common source term bin must have similar radiological release characteristics and potential off-site consequences. The application of release fractions to various time intervals must be explained and should be consistent with state of the art practices.

Evidence of benchmarking, comparisons, independent verification and peer review of source term calculations should be provided.

7.3.2.2 Dispersion

Atmospheric dispersion is causing transport and dilution of radionuclides into environment. The radionuclides released may be blown downwind, mix with the surrounding air, becoming diluted. Depending on physical form and chemical characteristics of the release, it may be deposited onto surfaces, thereby contaminating them. The main factors that influence the transport of material downwind are wind speed, wind direction and atmospheric stability.

A description of the code/model, the type of release (either a puff or continuous release) and the duration of the release should be specified. Topography, precipitation, atmospheric stability and mixing height should be specified. Building wake effects should be considered if there are buildings in the vicinity.

7.3.2.3 Meteorology

Meteorological data for the whole of the area covered by the consequence analysis are used in the determining of off-site consequences. This includes data which are specific to the site and national data if the consequence analysis needs to extend beyond this region. The meteorological data typically include:

- wind direction
- wind speed
- stability category
- rainfall
- mixing height.

Meteorological data from the meteorological station nearest to the release point and data compiled at other meteorological stations representative of the general conditions experienced by the plume and over the affected area should be used. If input is obtained from one station, weather data should be obtained at different height, e.g. 10 m and at 50 m. The meteorological data should be provided in a form that is suitable for the sampling scheme to be used in a computer software code for consequence calculations.

Site specific real time data collected over as long as possible, with a minimum period of one year, at specified time intervals e.g. hourly data should be statistically analyzed and averaged with a 95% confidence level. At least 2 sets of averaged data should be used. The first set should represent day time data and the second, night time data. The data collected should be representative of measurements taken a specific, but different heights, e.g. at 10m and at 50m. The following parameters should be included:

- *Fluctuations in wind direction;*
- *Air temperature and temperature lapse rate;*
- *Wind speed and solar radiation levels or sky cover during the daytime, and sky cover or net radiation levels at night-time;*
- *Wind speed at different heights;*
- *Precipitation; and*
- *Humidity.*

Information should be given to indicate the extent to which these data represent the historical meteorological characteristics of the site. This information may be obtained by comparing the local data with concurrent and historical data from synoptic meteorological stations in the surrounding area.

7.3.2.4 Countermeasures

Protective measures to mitigate the consequences of a nuclear or radiological accident can be divided into precautionary (preventive), urgent (early) and late (recovery) measures. A wide range of measures can be taken to protect or minimise the effects of radiation on the affected population.

In the consequence calculations, no credit should be taken for countermeasures such as sheltering, evacuation, administration of iodine tablets, relocation, food bans or decontamination.

7.3.3 Exposure Pathways and Dose Assessments

There are six principal pathways by which a radiation dose after a release of radioactive material into the atmosphere can be accumulated:

- External irradiation from radioactive material in the passing plume or cloud, referred to as ‘cloudshine’;
- External irradiation from radioactive material deposited on the ground, referred to as ‘groundshine’;
- External irradiation from radioactive material deposited on skin and clothing;
- Internal irradiation from radioactive material inhaled directly from the passing plume;
- Internal irradiation from radioactive material inhaled following resuspension of the ground deposit;
- Internal irradiation from radioactive material ingested following the contamination of foodstuffs by radioactive material deposited from the plume.

All the relevant exposure pathways should be considered, in determination of emergency zones, and justification should be provided to the regulator for those that are excluded.

Appropriate and latest dose conversion coefficients, factors and breathing rates should be used in dosimetric models. At each grid element around the release location, the following quantities can in principle be evaluated for the technical basis:

- *Concentrations of important radionuclides*
- *Radiation doses (individual, acute and chronic)*
- *Health effects (individual)*

7.3.4 Computer Codes and Models

The overall use of computer codes in reactor safety is well established internationally. Many codes have been developed and utilized in various applications. However, the user of the codes has full responsibility of ensuring that the codes they use are adequately qualified and suitable for their intended use. This includes defining the appropriate levels of detail for the modelling, documentation, verification, validation and accuracy necessary for the intended use of the codes.

The development, verifications, validation and application of evaluation and calculational models should in general be compliant with NNR requirements [10].

The acceptance of the calculational model or code by the NNR will be subject to the applicant justifying the use of the calculational model or code for the specific analysis considering its documented and validated domains.

The applicability domain of a calculational model or code used for the specific analysis should be demonstrated.

The following principles should be applied in the development of any calculational model[1]:

1. *determine requirements for the model*
2. *develop an assessment base consistent with the determined requirements*
3. *develop the model*
4. *assess the adequacy of the model*
5. *follow an appropriate quality assurance protocol during the process adopted*
6. *provide comprehensive, accurate, up-to-date documentation*

It is important that computer models and datasets used in support of the analysis should be developed, maintained and applied in accordance with appropriate quality assurance procedures.

Where applicable, internationally recognised nuclear industrial standards and/or practices or any other proposed, justifiable and acceptable best practices should be used. Considerations must only be given to qualified computer codes that comply with the above six principles if used for any licensing activity. Expert peer review of the above is embedded within principle five and an intrinsic part of the over-arching process.

7.3.5 Uncertainty Analysis

Uncertainties propagate through the whole evaluation model and may be of an aleatory (randomness) or epistemic (lack of knowledge) nature. Epistemic uncertainties include uncertainty in:

- Parameters – data used in the models
- Models – computer codes, event trees, source terms
- Scenarios – definition of Plant Damage States and Release Categories

[1] W*hether in Standardized plant analysis risk (SPAR) models, evaluation model development and assessment process (EMDAP) or Code Scaling, Applicability, and Uncertainty (CSAU) methodologies used in best estimate computer codes, in the application of the state-of-the-art reactor consequence analyses (SOARCA) process*

Uncertainties typically results from:

- Scenario uncertainty (completeness)
- Binning of sequences into Plant Damage States
- Definition release categories
- Simulation of the problem, including event tree construction and phenomenological models (computer codes) used to simulate the physical-chemical processes involved
- Data used to feed models
- Atmospheric dispersion models
- Meteorological database

It is necessary to estimate as accurately as possible all relevant output variables and to take into account uncertainties in the analyses. Monte Carlo methods could be used where possible and practical to account for uncertainty propagation in the evaluation models.

The evaluation model should generally be based on best estimate models that take into account uncertainty methodologies in their evaluation.

The calculation method should present a detailed derivation of the uncertainty bounds to be associated with important results. The modelling should provide a realistic calculation of any particular phenomenon to a degree of accuracy compatible with the current state of knowledge of that phenomenon. The neglect or simplification of any phenomenon should not be treated by including a deliberate pessimism or bias, but should form part of an assessment of the overall modelling uncertainty. In arriving at the overall calculational uncertainty all sources of uncertainty including scaling uncertainties and uncertainties associated with initial and boundary conditions should be taken into account. The methodology used to combine the various sources of calculation uncertainty should be described and justified. Judgements concerning dominant phenomena and key models should be clearly stated and justified. For each parameter, which is judged to be of particular significance to the derivation of the overall uncertainty, justification should be provided for the assumed uncertainty distribution of that parameter.

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

7.3.6 Sensitivity Analysis

Sensitivity analyses include systematic parameter ranging in code input variables or modelling parameters to determine the influence of important phenomena or models on the overall results of the analysis, particularly the key parameters for an individual event. Generally, in sensitivity studies a single modelling assumption or a single parameter value is changed and the outputs are recalculated in order to see how they vary. It is used to identify key analysis assumptions and parameter values which need to be included in any meaningful uncertainty analysis. Judgements in these areas are complex and require a detailed understanding of the interfaces and dependences between the many diverse analysis disciplines which include source term, atmospheric dispersion, emergency planning etc.

Established sensitivity analysis techniques should be used when pursuing different calculational objectives, all of them related to getting knowledge about the behaviour of the model/system studied, in other words, related to getting information about the input-output relation. Sensitivity analysis should be done to justify amongst others where relevant:

- *Plant damage states*
- *Selection of the reference accident*
- *Source terms used including release fractions, release height and timing of release*
- *Radionuclide grouping*
- *Release categories*
- *Weather categories (rain, etc)*
- *Major containment phenomena such as hydrogen explosion, direct containment heating, steam explosions, fission product transport/resuspension and core-concrete interaction.*
- *Radiological consequences (doses and health effects)*

7.4 Protective Action Implementation Timeframes

Implementation timeframes for all protective actions should be determined based on on-site and off-site parameters as well as in-plant and environmental conditions using acceptable methodologies. The technical basis should consider and include information on the capability to extend identified protective actions beyond the planning zones if it becomes necessary.
The times for protective actions should conform to available international guidance and recommendations and be synchronised with any other existing emergency procedures run by state or local authorities. In order to determine criteria for protective action implementation timeframes, the average warning times for the range of accidents selected should be taken into account.. For example for a reactor, an evaluation of the time of core uncovery, the time between core uncovery and release from containment of radionuclides for the selected accidents should be used.

7.5 Submissions to the NNR

The Emergency Planning Technical Basis should include but not be limited to the following:

- *Protection Strategy, including the reference levels and generic dose criteria*
- *An analysis identifying the range of potential and reference accident scenarios*

- *Assessment Methodology which should be discussed and should include the following elements:*
  - *Reference Accidents*
  - *Source Term Analysis*
  - *Meteorology and Atmospheric Dispersion*
  - *Population data*
  - *Consequence Assessment (projected doses)*
  - *Software Codes and Models*
  - *Uncertainty and Sensitivity Analysis*
- *Consequence calculations for all accident scenarios*
- *Results and Conclusions including*
  - *a sensitivity analysis of outputs associated with each scenario that forms part of the Reference Accidents*
  - *summary of the EPTB which should include the emergency planning zones, the derived sizes or radii of the zones, protective actions for the identified zones and practical implementation times thereof*

APPENDIX 1: REVIEW OF INTERNATIONAL PRACTICE

United States of America

In the US public protective actions are implemented on a precautionary basis following a number of events classified as a "General Emergency", under Appendix I of NUREG-0654 The actions specified would be implemented even if there was not subsequently an early radioactive release and there was no reason to believe that one would occur in the longer term (e.g. if containment isolation was achieved and there was no reason to expect it would fail). Two exposure pathways and, subsequently, two Emergency Planning Zones (EPZ) are defined:

- Plume exposure pathway – for which shelter and/or evacuation would be the principal protective actions. The principal exposure sources from this pathway are whole body external exposure to gamma radiation from the plume and deposited material, and inhalation exposure from the passing radioactive plume. In the region of the corresponding EPZ, with a radius of about 10 miles or 16 km, ("plume exposure pathway EPZ"), evacuation is the preferred action with evacuation out to a distance of 2 to 5 miles anticipated. The precise boundaries of these areas are recognised to be largely determined by political boundaries.
- Ingestion exposure pathway – for which control and interdiction in the human food chain would be the principal protective action. The principal exposure pathway is ingestion of contaminated water and foodstuff. This region ("ingestion control pathway EPZ") is of about 50 miles (or 80 km) radius.

According to /10 CFR 50.33(g)/ the exact size and configuration of the EPZs surrounding a particular nuclear power reactor shall be determined in relation to the local emergency response needs and capabilities, as they are affected by such conditions as demography, topography, land characteristics, access routes, and jurisdictional boundaries. The size of the EPZs also may be determined on a case-by-case basis for gas-cooled reactors and for reactors with an authorized power level less than 250 MW thermal. The plans for the ingestion pathway shall focus on such actions as are appropriate to protect the food ingestion pathway.

Different zones are defined for the siting of new nuclear power plants. The zoning used for the siting process is regulated in the "Reactor Site Criteria" /10 CFR 100/. An important factor for the site approval is that the proposed site will be away from densely populated centers. Therefore the following siting zones are defined:

- The Exclusion Area means that area surrounding the reactor, in which the licensee has the authority to determine all activities including exclusion and removal of personnel or property from the area. Residence within the Exclusion Area shall normally be prohibited. In any event, residents shall be subject to ready removal in the case of necessity.
- The Low Population Zone means the area immediately surrounding the exclusion area which contains residents, the total number and density of which are such that there is a reasonable probability that appropriate protective measures could be taken on their behalf in the event of a serious accident. The US guides do not specify a permissible population density or total population within this zone because the situation may vary from case to case.

- Additionally, a Population Center Distance is defined as the distance from the reactor to the nearest boundary of a densely populated center containing more than 25000 residents.

For existing reactors (applications before January 1997) additional siting regulations exist:

- The Exclusion Area is determined to be of such size that an individual located at any point on its boundary for two hours following onset of the postulated fission product release would not receive a total radiation dose to the whole body in excess of 25 rem (i.e. 250 mSv) or a total radiation dose in excess of 300 rem (i.e. 3 Sv) to the thyroid from iodine exposure.
- The Low Population Zone is determined to be of such size that an individual located at any point on its outer boundary 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 total radiation dose to the whole body in excess of 25 rem (i.e. 250 mSv) or a total radiation dose in excess of 300 rem (i.e. 3 Sv) to the thyroid from iodine exposure.
- The Population Center Distance is determined to be at least one and one-third times the distance from the reactor to the outer boundary of the low population zone. The boundary of the population center shall be determined upon consideration of population distribution. Where very large cities are involved, a greater distance may be necessary because of total integrated population dose considerations.

For site applications after January 1997 these additional regulations do not apply any more with the exception of the regulations concerning the Population Center Distance. Nevertheless they are important to understand the ideas behind the zoning definitions within the siting process.

Russia

The Russian regulations require definition of a 30 km emergency planning zone around all nuclear power plants. Federal law establishes:

- 3 km exclusion zone - where no public housing is allowed,
- 5 km protection zone - within which the plant is responsible for notifying the public of any early precautionary actions they should be taking,
- 30 km surveillance zone – with radiation monitors,
- on site radiation monitors to measure on site dose rates and support off site dose calculations.

The Russian criteria for radiological protective actions are:

- 50 mSv for mandatory sheltering, based on the 10 day total effective dose equivalent,
- 500 mSv for mandatory evacuation, based on the 10 days total effective dose equivalent,
- 0.1-1 Sv thyroid dose for administration of stable iodine to children,
- 0.25-2.5 Sv thyroid dose for administration of stable iodine to adults.

Source term estimation is provided by a computer code that uses assumptions based on design basis and beyond design basis accidents as well as on-site and off-site monitoring results.

European countries

Germany

Germany changed its emergency zoning concept in 2008. There are four emergency planning zones in the environs of nuclear power plants:

a) Central Zone with a radius of not more than 2 km
b) Intermediate Zone with a radius of about 10 km
c) Extended Zone with a radius of about 25 km
d) Far Field Zone with a radius up to 100 km

The emergency planning zones b) to d) are divided into 30° sectors.

In emergency planning zones a) and b) all emergency actions (especially sheltering, evacuation, iodine pills, but also some additional actions) have to be executed on a short time scale and thus have to be preplanned.

In emergency planning zone c) the distribution of iodine pills and radiological measurements have to be pre-planned. Finally, in the far field emergency planning zone the distribution of iodine pills for children and pregnant women shall be pre-planned. Warnings on the use of freshly harvested food shall be issued in all four emergency planning zones.
Iodine pills shall be pre-distributed up to a distance of about 6 km. The distribution of iodine pills in all other emergency planning zones shall be completed within 12 hours (after the decision for distribution).

The Central Zone is not an exclusion zone. However, in the siting procedure (which has not been used in the last 30 years) the existence of hospitals, prisons and nursing homes as well as high population densities will give a bad ranking.
The emergency zoning additionally is used to define the responsibility for the required measurements. The operator has to perform measurements in the Central Zone as well as in the sectors of the Intermediate Zone with the highest releases, while the regulator is responsible for measurements in all other sectors and zones.

The general protective actions, for which emergency planning exists, are based on projected dose calculations:

- Sheltering - based on an effective dose > 10 mSv (calculated over 7 days),
- Evacuation - based on an effective dose > 100 mSv (calculated over 7 days),
- Iodine tablets - based on an effective dose to an adult > 250 mSv, (children of age below 18 years > 50 mSv),
- Temporary relocation - based on an effective dose stemming from the contaminated ground > 30 mSv (calculated over 30 days),
- Relocation – based on an effective dose in first year stemming from the contaminated ground > 100 mSv.

These values, especially with respect to integration times, are currently under revision.

Belgium

The general protective action radii for which emergency planning exists, are:

- 10 km evacuation zone, (also predistribution of iodine pills)

- 10 km sheltering zone,
- 20 km zone for distribution of stable iodine
- Whole country food chain intervention zone.

It is stated that the size of these protective action radii have been defined taking into account a rough estimate of the risk.
Dose reference levels are based on the concept of avertable dose.

- Sheltering: 5 – 15 mSv effective dose within 24 h from external exposure and inhalation
- Evacuation: 50 – 150 mSv effective dose within 14 days from external exposure and inhalation
- Iodine tablets: 50 mSv for children and adults.

Czech Republic

The general protective action radii, for which emergency planning exists, are:

- 5 km evacuation zone around Temelin NPP, 10 km evacuation zone around Dukovany NPP,
- 13 km sheltering and distribution of stable iodine zone around Temelin NPP,
- 20 km sheltering and distribution of stable iodine zone around Dukovany NPP.

The difference in the protective action radii for Temelin NPP and Dukovany NPP is claimed to be due to differences in population density, meteorology and evacuation conditions. For Temelin NPP, the Level 2 PSA results have been used to show that no sequences have been identified with more serious consequences than those used as the basis of the protective action radii.

Finland

Detailed emergency planning exists for:

- distribution of stable iodine and implementation of early countermeasures within a 5 km zone,
- a ‘rescue service plan’ within an emergency preparedness zone in excess of 20 km.

Additionally, no population centres or other activities that are deemed to be difficult to evacuate are allowed within the emergency preparedness zone.

Hungary

The general emergency planning zones, for which emergency planning exists, are:

- 3 km precautionary action zone,
- 30 km urgent protective action zone,
- 80 km long term protective action zone.

The emergency zoning is stated to be based on a number of accident scenarios with different releases and exposure pathways. Thus, a single bounding accident is not defined. However, it is claimed that a serious accident sequence was considered during the emergency planning process.

The Netherlands

The general protective action radii, for which emergency planning exists, are (for NPP with 100 to 500 MWe):

- 5 km evacuation zone,
- 10 km zone for distribution of stable iodine,
- 20 km zone for sheltering.

Emergency response, in case of nuclear emergencies, is co-ordinated at a national level.

Slovak Republic

The general emergency planning, is based on a 'hazard area' of radius 30 km for Bohunice NPP and 20 km for Mochovce NPP. The difference in the emergency planning zone sizes for Bohunice NPP and Mochovce NPP is claimed to be due to differences in population density, meteorology and evacuation conditions.

Action	**Reference level (avertable dose)**	**Integration time**
Sheltering	10 mSv effective dose	Within 2 days
Iodine pills	100 mGy organ dose (energy dose)	Passage of the cloud
Evacuation	50 mSv effective dose	Within 7 days
Temporal relocation	30 mSv in the first month 10 mSv in the following months	
Permanent relocation	1000 mSv effective dose	Within life (50 years)

The protective action radii are defined for the worst reasonably foreseen accident scenario. The reference accident is a large LOCA, leading to core damage and reactor pressure vessel failure.

United Kingdom

Emergency Reference Levels are a specific example of ILs used in the UK, specified by the Health Protection Agency (HPA) (formerly NRPB), in terms of avertable doses. As for ILs, it is not intended that ERLs should be applied directly to determine the optimum urgent response to an actual accident; rather they should be used in the development of emergency plans. However, following initiation of the emergency plan in response to an actual accident, they could be used as a standard against which to check on the broad adequacy of the countermeasures being implemented.
When calculating averted doses for comparison with the ERLs, it is considered inappropriate to use assumptions of extreme or very unusual behaviour – the ERLs were developed for children and, strictly, the averted doses to be compared with them should be doses to children. Upper and lower ERLs are defined for urgent protective actions: sheltering, evacuation and iodine tablets distribution.

Table 0-1 UK Recommended ERLs for urgent countermeasures

Countermeasure	Body organ	Dose equivalent level (mSv)	
		Lower	**Upper**
Sheltering	Whole body Thyroid, lung, skin	3 30	30 300
Evacuation	Whole body Thyroid, lung, skin	30 300	300 3000
Administration of Stable Iodine	Thyroid	30	300

To retain the flexibility to match actions to conditions at the time of an accident, the HPA recommends the use of a lower and upper ERL for each countermeasure, where:

- The Lower ERL is the dose level below which the countermeasure should not be introduced because, in the Board's judgments, it would be very unlikely to be justified to do so.
- The lower ERL is appropriate for circumstance where the disadvantages of implementing the countermeasures are judged to be small (few people would be involved and the implementation of the countermeasure has been planned in detail in advance)
- If estimated averted doses exceed the lower ERL, implementation of the countermeasure should be considered but is not essential.
- The upper ERL is the dose level at which the Board expects every effort to be made to introduce the countermeasure unless it would clearly contravene the principles of justification and optimisation to do so.
- The upper ERL applies to situations where the disadvantages of implementing the countermeasures are judged to be large (where many people would be involved or where the implementation of the countermeasure had not been planned in advance).

It is also necessary to check that total doses to individuals will be below the thresholds at which deterministic effects may occur, because this will take precedence. That is, if these thresholds are likely to be exceeded if no countermeasures are implemented, the countermeasures should be implemented even if the averted dose is below the ERL, in order for the total dose to remain below threshold.

In the UK a Detailed Emergency Planning Zone (DEPZ) is defined around all nuclear installations where there is the potential for an off-site release of radioactivity that would require implementation of protective actions. The DEPZ is defined on the basis of the most significant release of radiation from an accident which can be reasonably foreseen. In the event that the accident is larger than the reasonably foreseen event, arrangements are in place for extending the DEPZ – so called extendibility arrangements.

For AGR sites a 1 km DEPZ is defined as an appropriate minimum distance for emergency planning purposes, consistent with reasonably foreseen accidents leading to a predicted off-site dose exceeding the lower ERL for evacuation. For other sites the DEPZ in place ranges from 1 km to 3 km.
Population density constraints have been applied for specific licensed sites. The existence of a controlled 'low population zone' around a nuclear licensed site is considered to represent a buffer between the nuclear licensed site boundary and more concentrated centres of population. This is seen as the only effective non-engineered means of restricting exposure

of the local population to radiation in the event of a potential release of radioactive material into the environment following a significant plant fault.
In the DEPZ, constraints on new developments apply to ensure that residential, industrial and commercial developments are so controlled that the general characteristics of the site are preserved and maintained throughout the entire life cycle of the nuclear installation.

India

In India, NPPs are generally sited in relatively low-population zones. The area around the NPP is divided into the following zones:

- Exclusion zone – an area of 1.5 km radius around the plant, which is under the exclusive control of the operating organization, and no public habitation is permitted in the area. The entire area is fenced or walled off and defines the boundary of the site.
- Sterilized zone - with the help of administrative measures, efforts are made to establish a sterilized zone up to a 5-km radius around the plant. This is the annulus around the exclusion zone, which has the potential for extensive contamination in case of a severe accident. Development activities within this area are controlled so as to check an uncontrolled increase in the population. In this area, only natural growth of the population is permitted.
- Emergency planning zone – an area of up to a 16-km radius. This zone is examined in great detail while drawing up an offsite emergency plan and arranging logistics for the same. This zone is divided into 16 equal sectors. The objective is to optimize the emergency response mechanism and to provide the maximum attention and relief to the region most affected during an offsite emergency.

Japan

The general emergency planning zone, for commercial plants and research reactors with power levels greater than 50 MWth, is about 8 to 10 km. The zone boundary is defined to limit public exposure to 10 mSV (whole body) or 100 mSv (thyroid). The results of Level 2 PSA (source terms and frequencies for a range of accident sequences) are used as the basis for developing the emergency plan.

France

Around each NPP there are two zones defined. The emergency planning zone of 5 km radius around a nuclear power plant is the zone where evacuation is pre-planned and prepared in detail. The emergency planning zone of 10 km radius around a NPP is the zone where sheltering is pre-planned.

Stable iodine tablets have been previously distributed in France to the population within a radius of 10 km around a NPP. The emergency planning zones of 5 km and 10 km radii around a NPP provide reasonable assurance that the doses to the population in the short term would be below the different intervention levels for a spectrum of accidents and radionuclide releases, in particular for most core melt accidents. Another important consideration is that 5 and 10 km are practicable distances for planning in France. It is also recognized that protective actions could be extended beyond 10 km if conditions warrant. Much more time would be available for emergency response beyond these distances. Concerning intervention levels, sheltering is recommended when the projected effective dose exceeds 10 mSv, whereas evacuation is recommended when this dose exceeds 50 mSv. The intake of stable iodine is recommended when the thyroid committed equivalent dose by inhalation exceeds 100 mSv for most sensitive population [9].

The establishment of emergency planning zones defined based on a deterministic approach, and the use of a reference source term is practised in France. Three general classes of severe accidents with core meltdown were distinguished as a basis for designing the French severe accident policy and making operational decisions:

- Accidents resulting in “early” failure of the containment (ST1).
- Accidents resulting in “delayed” failure of the containment, at least 24 hours after the beginning of the accident, without filtration of the corresponding releases (ST2).
- Accidents resulting in “delayed” failure of the containment, at least 24 hours after the beginning of the accident, with releases in a way ensuring some filtration (ST3).

There is, in orders of magnitude, a factor of roughly 10 between source terms ST1 and ST2 and a factor of 10 between source terms ST2 and ST3. The accidents corresponding to source term ST1 are considered as improbable. Source term ST3 was adopted as the maximum conceivable release for French nuclear power units. It does not correspond to a particular scenario but is a reasonable envelope of the releases of various scenarios. It covers a set of possible scenarios and is not related to a precise accident scenario.

The source term ST3 is used as a technical basis for emergency plans for protection of the civil population, for determining the response of the utility and the public authorities concerned. The source term consequence assessment has a direct impact on the establishment of EP zones, protective actions, resources, procedures and the requirements for a preparedness organization. Emergency plans in France are designed to cope, as far as possible, with the consequences of a ST3 type release. The results of the ST3 source term consequences calculations were compared to the intervention levels recommended in France by the Ministry of Health, to determine to which distance the respective countermeasures should be prepared.

The radiological consequences of a ST3 type release and their evolution in time were assessed for both the adult and the one-year-old child, in the vicinity of the NPP (from 1 to 20 kilometres). Respecting the recommended intervention levels implies the possibility of evacuating the population within a radius of 5 kilometres and of confining the population indoors within a radius of 10 kilometres around the NPP within less than 24 hours, which is in accordance with what is planned in emergency plans. The doses assessment also showed that evacuation of the population within a radius of 2 kilometres around the NPP must not be delayed in the case of a ST3 type release, which reinforced the interest of the creation of a respond action stage in off-site emergency plans.

The thyroid committed equivalent dose is the most restrictive equivalent dose. The ST3 consequences could result in the decision, to be taken within 12 to 24 hours, to organise absorption of stable iodine within a radius of 10 kilometres and in the decision to be taken before 48 hours, to organise absorption of stable iodine within a radius of less than 20 kilometres from the plant.

Australia

Australia has defined ILs as well as OILs, based on the IAEA recommendations.

Protective Action	**Avertable Dose RPS7**	**Increased Cancer Risk (lifetime)**
Urgent		
Evacuation	50 mSv	20 per 10000
Sheltering	10 mSv	4 per 10000
Stable Iodine Prophylaxis	100 mGy (Adults) 30 mGy (Child)	2 per 10000 (Adults) 4 per 10000 (Children)
Longer Term		
Temporary Relocation	30 mSv in 1st month 10 mSv in subsequent month	16 per 10000
Permanent Resettlement	1 Sv in lifetime	400 per 10000

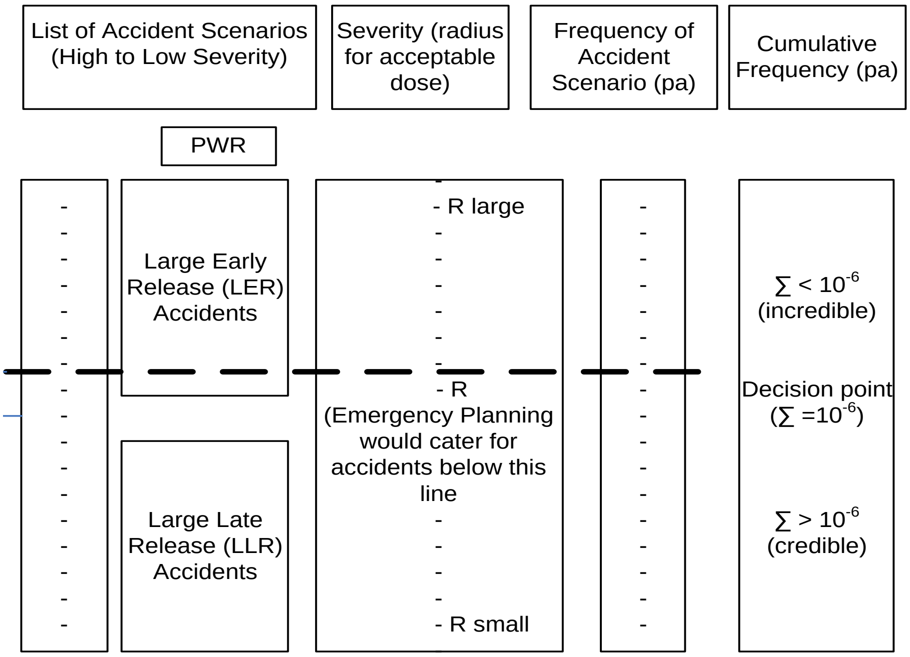
APPENDIX 2: DECISION PROCESS FOR CHOICE OF REFENCE ACCIDENTS

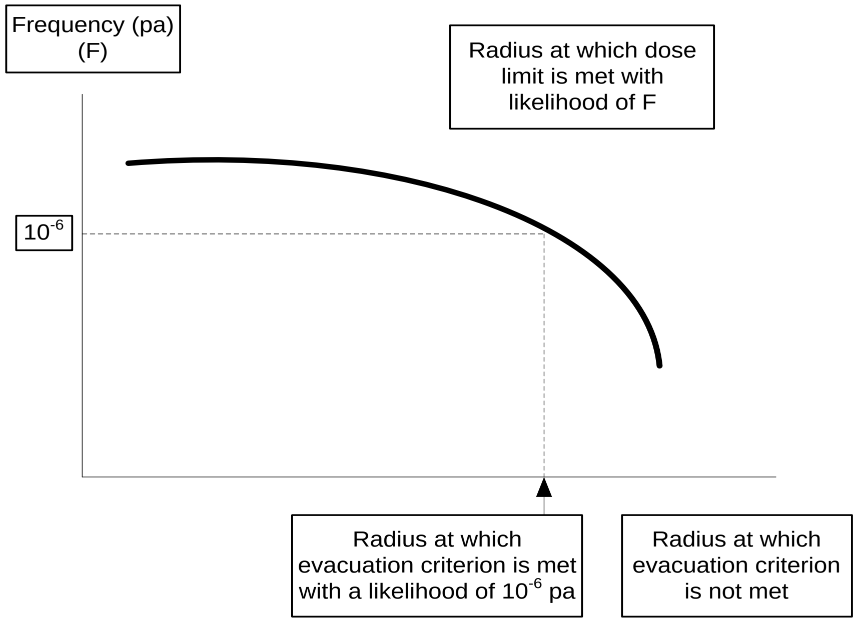
Conceptually the processes of interrogating the accident scenarios can be characterized as follows. The PSA provides the frequency (pa) of each accident sequence, and the consequence of the accident sequence in terms of dose to the public. For each accident scenario the radius R at which the dose criteria for evacuation are exceeded can be determined. The results can be tabulated as shown in the figure below with the accident scenario listed in descending order of R, and the frequency of each accident scenario given in the third column. In the fourth column the sum over the frequencies of the accident scenario exceeding the corresponding value of R is given. This represents the cumulative frequency of events which would require evacuation of the public beyond the point R.

A graph can be drawn of this cumulative frequency (F) as a function of R. The graph will always decrease with larger radius R as the likelihood for exceeding any particular dose will get smaller at larger distances.

The desired EZ radius is the value of R at which the likelihood of exceedance of the evacuation criteria equals 10^{-6} pa. On the graph this is given by the value of R corresponding to 10^{-6} pa. This means that the likelihood of having to conduct evacuation beyond this point is 10^{-6} pa. The "Reference Accident" would be the accident or group of accidents closest to this point on the graph.

Care has to be taken not to interpret such a graph too literally as there is considerable variance on the output of the PSA. The uncertainties need to be estimated, and the final decision on the EZ radius should take into account these variances.


List of Accident Scenarios (High to Low Severity)
Severity (radius for acceptable dose)
Frequency of Accident Scenario (pa)
Cumulative Frequency (pa)
PWR
Large Early Release (LER) Accidents
Large Late Release (LLR) Accidents
- R large
- R
(Emergency Planning would cater for accidents below this line
- R small
∑ < 10-6 (incredible)
Decision point (∑ =10-6)
∑ > 10-6 (credible)


Frequency (pa) (F)
Radius at which dose limit is met with likelihood of F
10-6
Radius at which evacuation criterion is met with a likelihood of 10-6 pa
Radius at which evacuation criterion is not met

APPENDIX 3: GENERIC CRITERIA FOR ACUTE DOSES FOR WHICH PROTECTIVE ACTIONS AND OTHER RESPONSE ACTIONS ARE EXPECTED TO BE TAKEN UNDER ANY CIRCUMSTANCES TO AVOID OR TO MINIMIZE SEVERE DETERMINISTIC EFFECTS.

Generic criteria		Examples of protective actions and other response actions
External acute exposure (<10 hours)		If the dose is projected:
$AD_{Red\ marrow}$[a]	1 Gy	— Take precautionary urgent protective actions immediately (even under difficult conditions) to keep doses below the generic criteria — Provide public information and warnings — Carry out urgent decontamination
AD_{Fetus}	0.1 Gy	
AD_{Tissue}[b]	25 Gy at 0.5 cm	
AD_{Skin}[c]	10 Gy to 100 cm^2	
Internal exposure from acute intake (Δ= 30 days)[d]		
$AD(\Delta)$Red marrow	0.2 Gy for radionuclides with $Z \geq 90$[e] 2 Gy for radionuclides with $Z \leq 89$[e]	
$AD(\Delta)_{Thyroid}$	2 Gy	
$AD(\Delta)_{Lung}$[g]	30 Gy	
$AD(\Delta)_{Colon}$	20 Gy	
$AD(\Delta')_{Fetus}$[h]	0.1 Gy	

[a] $AD_{Red\ marrow}$ represents the average 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] 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).

[c] 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 body surface).

[d] $AD(\Delta)$ is the RBE weighted absorbed dose delivered over the period of time Δ by the intake (I_{05}) that will result in a severe deterministic effect in 5% of exposed individuals.

[e] Different criteria are used to take account of the significant difference in the radionuclide specific intake threshold values for the radionuclides in these groups [7].

[f] For the purposes of these generic criteria, 'lung' means the alveolar-interstitial region of the respiratory tract.

[g] For this particular case, Δ'means the period of in utero development.

APPENDIX 4: GENERIC CRITERIA FOR PROTECTIVE ACTIONS AND OTHER RESPONSE ACTIONS IN EMERGENCY EXPOSURE SITUATIONS TO REDUCE THE RISK OF STOCHASTIC EFFECTS

Generic criteria		Examples of protective actions and other response actions
Projected dose that exceeds the following generic criteria: Take urgent protective actions and other response actions		
$H_{Thyroid}$	50 mSv in the first 7 days	Iodine thyroid blocking
E	100 mSv in the first 7 days	Sheltering, evacuation; decontamination; restriction of consumption of food, milk and water; contamination control; public reassurance
Projected dose that exceeds the following generic criteria: Take protective actions and other response actions early in the response		
E	100 mSv per annum	Temporary relocation; decontamination; replacement of food, milk and water; public reassurance

Note: H_T — equivalent dose in an organ or tissue T; E — effective dose.