Commission for Energy Regulation

An Coimisiún um Rialáil Fuinnimh

ALARP Demonstration Guidance Document under the Petroleum Safety Framework

DOCUMENT TYPE:	**Draft Guidance Document issued for Consultation**
REFERENCE:	**CER/12/181**
DATE PUBLISHED:	6th November 2012
CLOSING DATE:	21st December 2012
RESPONSES TO:	Eamonn Murtagh

The Commission for Energy Regulation,
The Exchange,
Belgard Square North,
Tallaght,
Dublin 24.
www.cer.ie

Consultation Process for the ALARP Demonstration Guidance Document

The *Electricity Regulation Act 1999*, as amended *inter alia* by the *Petroleum (Exploration and Extraction) Safety Act 2010* (the 'Act') gives the Commission for Energy Regulation (CER) responsibility for the safety regulation of petroleum exploration and extraction activities in Ireland. The Act specifically includes a requirement for the CER to "establish and implement a risk-based petroleum safety framework" (collectively referred to in this document as the 'Framework'). The Framework can be best understood as the entire system that the CER will use to regulate the safety of petroleum activities[1], and in particular designated petroleum activities[2], carried out by petroleum undertakings[3].

In June 2012, the CER published the *Decision Paper on the High Level Design of the Petroleum Safety Framework* (the 'High Level Design[4]'). The High Level Design frames the key policy aspects and principles of the Framework to be subsequently reflected in the underlying guidance, regulations and written regulatory documents and procedures.

The development of the High Level Design was subject to a two stage public consultation process. In August 2011, the CER published the *Consultation Paper on the High Level Design of the Petroleum Safety Framework* (the 'High Level Design Consultation Paper'[5]), which set out proposals for the high level design of the Framework and invited responses from the public. Following consideration of the responses received, the CER published its *Draft Decision on the High Level Design of the Petroleum Safety Framework* (the 'High Level Design Draft Decision'[6]) in February 2012, which included a number of changes from the proposals/options in the High Level Design Consultation Paper. The CER again received a significant number of responses to the Draft Decision Paper and following their consideration, the CER published the High Level Design.

A key element consulted upon by the CER in the above process was the CER's high level requirements with respect to demonstration of *ALARP* under the Framework. Those high level policy requirements are set out in the High Level Design and are not the subject of further consultation in this consultation paper (the 'Paper'). This purpose of this Paper is to set out for consultation the CER's detailed *ALARP Demonstration Guidance Document*. The *ALARP Demonstration Guidance Document* expands on the high level requirements set out in the High Level Design and provides further detail of the CER's expectations with respect to ALARP demonstrations under the Framework and within the policy limits set out in the High Level Design. While the policy is not for consultation, the CER invites comments on detailed aspects of the ALARP demonstration. In particular, the CER invites comments on:

1) proposals for Risk Tolerability Limits (see Section 5 & Appendix D);
2) criteria for the Implied Cost of Averting a Fatality (Appendix B); and

---

[1] As defined in Section 13A(2) of the Act.
[2] A designated petroleum activity is a petroleum activity designated as such by the CER by regulation pursuant to Section 13D of the Act.
[3] As defined in Section 13A(1) of the Act.
[4] See *Decision Paper on the High Level of the Petroleum Safety Framework* (CER/12062).
[5] See *Consultation Paper on the High Level Design of the Petroleum Safety Framework* (CER/11137).
[6] See *Draft Decision Paper on the High Level Design of the Petroleum Safety Framework* (CER/12017).

3) the Gross Disproportion Factor (Appendix C).

Interested parties are invited to provide written responses to the proposed text of the *ALARP Demonstration Guidance Document* set out in this Paper. Comments should be sent by the December 13th 2012, preferably in electronic format to:

Eamonn Murtagh
Commission for Energy Regulation
The Exchange
Belgard Square North
Tallaght
Dublin 24
emurtagh@cer.ie

The CER intends to publish all comments received on the CER website. Respondents wishing for their submission, or sections therein, to be treated as confidential should note this in their submission.

Should a respondent wish to meet with the CER to discuss its submission, the CER will make itself available for such meetings in the week commencing January 7th 2012. Respondents wishing to meet with the CER to discuss their submissions should contact Tina Graham at the CER no later than 1pm December 20th 2012.

Table of Contents

List of Figures and Tables

List of Figures

List of Tables

Appendices

Glossary of Terms and Abbreviations

List of Abbreviations

Abbreviation	Meaning
(the) Act	The Electricity Regulation Act, 1999 as amended, inter alia, by the Petroleum (Exploration and Extraction) Safety Act 2010
ALARP	As Low As is Reasonably Practicable
CER	Commission for Energy Regulation
FN	A measure of societal risk where F is the cumulative frequency of N or more fatalities
HSA	Health and Safety Authority
HSE	UK Health and Safety Executive
ICAF	Implied Cost of Averting a Fatality
NSAI	National Standards Authority of Ireland
QRA	Quantitative Risk Assessment

List of Defined Terms in this Paper

Words and phrases defined in Section 13A of the Act shall, unless the context otherwise requires, have the same meanings when used in this Paper.

Term	Definition /Meaning
ALARP Demonstration Guidance Document	This guidance document, which details CER's expectations on ALARP demonstration under the Framework. The ALARP Demonstration Guidance Document forms part of the Framework.
Defined ICAF	The Defined ICAF is an advised minimum value to be ascribed to ICAF for use in a cost benefit analysis, which may be published by CER from time to time and at the date of this ALARP Demonstration Guidance Document is €2,400,000.
FN curve	An FN curve plots the cumulative frequency of N or more fatalities over the range of fatalities possible
Framework	The Petroleum Safety Framework established under section 13I of the Act which comprises a collection of regulations, written regulatory documents and procedures which, taken together, describe the system the CER will use to regulate the activities of petroleum undertakings with respect to safety. .
General Duty	The duty placed on petroleum undertakings under section 13K of the Act to ensure that: a) any petroleum activity is carried on in such a manner as to reduce any risk to safety to a level that is As Low As is Reasonably Practicable (ALARP); and b) any petroleum infrastructure is designed, constructed, installed, maintained, modified, operated and decommissioned in such a manner as to reduce any risk to safety to a level that is ALARP
Good Practice	The recognised risk management practices and measures that are used by competent organisations to manage well-understood hazards arising from their activities.
Gross Disproportion Factor	The minimum factor by which the calculated ICAF of a risk reduction measure must exceed the Defined ICAF for the cost of the risk reduction measure to be in gross disproportion to its safety benefit and therefore for it to be considered not reasonably practicable to implement the measure; which for the purposes of this *ALARP Demonstration Guidance Document* is advised not to be less than 10.
Hazard	Source of potential harm

Term	Definition /Meaning
High Level Design	The CER *Decision Paper on the High Level Design of the Petroleum Safety Framework* (the High Level Design[7]) as amended from time to time
Implied Cost of Averting a Fatality (ICAF)	This is the cost of a risk reduction measure divided by the reduction in risk that it achieves.
Individual risk	The risk to an individual
Lower Tolerability Limit	The boundary between risks described as broadly tolerable and risks which are tolerable if ALARP.
Major Accident	An event, such as a major emission, fire, explosion, impact or structural failure of petroleum infrastructure, resulting from uncontrolled developments in the course of designated petroleum activities that could lead to a serious danger to human health whether immediate or delayed. Serious danger implies events which could impact multiple persons, including members of the public and/or workforce
Major Accident Hazard	A hazard that if realised could result in a Major Accident
Residual risk	The risk that remains once a risk reduction measure has been implemented
Risk	The likelihood of a given consequence
Risk assessment	The overall process of hazard identification, risk analysis and risk evaluation
Risk analysis	Process to determine and comprehend the nature and the level of risk. Risk analysis provides the basis for risk evaluation
Risk evaluation	Process of comparing the results of risk analysis with risk limits to determine whether the risk is tolerable
Risk reduction measure	A measure that reduces the risk of hazard from a petroleum activity. In ALARP demonstrations, consideration of risk reduction measures includes new measures, or measures that are improved through better technology, maintenance, operational procedures, or similar
Risk Tolerability Limits	The Upper Tolerability Limit and / or Lower Tolerability Limit for individual, or societal risk, as the context requires.
Safety Case Guidelines	Guidelines prepared by the CER under section 13L of the Act relating to the preparation and appropriate contents of safety cases for petroleum undertakings. The Safety Case Guidelines form part of the Framework.
Societal risk	The risk to all persons that are affected by a hazard
Upper Tolerability Limit	The boundary between risks described as intolerable and risks which are tolerable if ALARP.

[7] See Reference 1 in Appendix I.

1 Introduction

1.1 The Petroleum Safety Framework

The *Electricity Regulation Act 1999*, as amended *inter alia* by the *Petroleum (Exploration and Extraction) Safety Act 2010* (the Act) gives the Commission for Energy Regulation (CER) responsibility for the safety regulation of petroleum exploration and extraction activities in Ireland. The Act specifically includes a requirement for the CER to "establish and implement a risk-based Petroleum Safety Framework" (collectively referred to in this document as the Framework). The Framework can be best understood as the entire system that the CER will use to regulate the safety of petroleum activities[8], and in particular designated petroleum activities[9], carried out by petroleum undertakings[10]. The Framework established by the Act is to be risk-based, recognising that hazards may be presented by the activities to be regulated and it requires petroleum undertakings to reduce risks to a level that is as low as is reasonably practicable (ALARP).

The CER *Decision Paper on the High Level Design of the Petroleum Safety Framework*[11] (the 'High Level Design') sets out, at a high level, how the Framework operates. This *ALARP Demonstration Guidance Document* forms part of the Framework.

1.2 Purpose of ALARP Demonstration Guidance Document

The purpose of the *ALARP Demonstration Guidance Document* is to provide detailed guidance to petroleum undertakings of CER's expectations on what will constitute a sufficient ALARP demonstration under the Framework.

It is the responsibility of the petroleum undertaking to ensure that the risks from its activities are reduced to a level that is ALARP and to demonstrate this through its safety case (or cases). It is for the petroleum undertaking to decide how best to demonstrate that the risks from their activities are ALARP through its safety case. The CER will assess whether it considers the demonstration to be adequate or not given the full array of information provided, and having regard to the requirements of the Act and of the Safety Case Guidelines. The ALARP demonstration will form a central part of the safety case or safety cases submitted by the Petroleum Undertaking under the Act.

The *ALARP Demonstration Guidance Document* is intended to reflect best international practice in this field. In preparing the ALARP Demonstration Guidance Document, the CER has drawn on guidance issued by other statutory bodies regulating safety in the petroleum exploration and extraction industries in the UK and Australia. The CER may amend the *ALARP Demonstration Guidance Document* from time to time to take account of changes in national or international practice.

---

[8] As defined in Section 13A(2) of the Act.

[9] A designated petroleum activity is a petroleum activity designated as such by the CER by regulation pursuant to Section 13D of the Act.

[10] As defined in Section 13A(1) of the Act.

[11] See Reference [1]. See Figure 8 Overview Diagram of Framework in Appendix E.

1.3 Structure of the Document

The *ALARP Demonstration Guidance Document* is divided into 4 further sections:

- **Legal Context** (Section 2), provides a high level overview of the legal context relevant to the application of the ALARP principle in Ireland;

- **The ALARP Principle and ALARP Demonstration** (Section 3), provides an overview of the ALARP principle and sets out the general requirements for ALARP demonstration under the Framework;

- **ALARP Assessment** (Section 4), provides guidance on ALARP assessment to be carried out by petroleum undertakings which involves applying an overall hazard management process which incorporates the ALARP principle; and

- **Risk Tolerability Limits** (Section 5), provides advisory guidance on the individual and societal risk limits that petroleum undertakings will be expected to abide by as part of the ALARP assessment process.

2 Legal Context

Under the Act, petroleum undertakings are subject to a General Duty which requires them to ensure that (a) any petroleum activity is carried on in such a manner as to reduce any risk to a level that is as low as is reasonably practicable, and (b) any petroleum infrastructure is designed, constructed, installed, maintained, modified, operated and decommissioned in a manner as to reduce any risk to a level that is as low as is reasonably practicable[12].

The concept of what is 'reasonably practicable' was considered by the Court of Appeal in the UK in the case of *Edwards v National Coal Board 1949*[13] where Asquith L.J. held:

> "*'Reasonably practicable' is a narrower term than 'physically possible', and seems to me to imply that a computation must be made by the owner in which the quantum of risk is placed on one scale and the sacrifice involved in the measures necessary for averting the risk (whether in money, time or trouble) is placed in the other, and that, if it be shown that there is a gross disproportion between them – the risk being insignificant in relation to the sacrifice – the defendants discharge the onus on them*"

The definition of "reasonably practicable" espoused in the *Edwards* case is followed in Ireland and was applied by the Supreme Court in the case of *Boyle v Marathon Petroleum (Irl) Ltd* 1999[14]. The Supreme Court, in dealing with the concept of "reasonably practicable", indicated that the approach involved three elements. First, the onus of proving that all that is reasonably practicable has been done lies on the duty holder; second, the duty is higher than the common law duty of care; and third, cost is not always to be a factor in determining whether "reasonably practicable" precautions have been taken, but equally a balance has to be struck between the high risk removed by a particular precaution and the remaining low risk created.

The courts in Ireland have accepted the UK position that in applying the ALARP standard, the measure necessary for averting the risk must be adopted unless the sacrifice involved in that measure is grossly disproportionate to the risk. The ALARP principle arises from the fact that infinite time, effort and money could be spent on the attempt of reducing a risk to zero and some limit must be placed on how far a duty holder must go to discharge their duty. What is reasonably practicable in any given situation will be determined by the facts of the case.

---

[12] Section 13K of the Act.
[13] See *Edwards v National Coal Board* [1949] 1.K.B. 704.
[14] See *Boyle v Marathon Petroleum (Irl) Ltd* [1999] 2 I.R. 460.

3 The ALARP Principle and ALARP Demonstration

3.1 Overview of ALARP Principle

The fundamental obligation placed upon petroleum undertakings under the Act is to reduce any risks to safety to a level that is as low as is reasonably practicable (ALARP). This is based on the principle that those who create and have control over risks have responsibility for their management and must actively assess them in order to ensure that sufficient risk reduction measures are implemented such that the risk is ALARP. A key regulatory goal of the Framework is to ensure that petroleum undertakings fulfil this obligation.

The fundamental principle of risk-based hazard management is that whilst risks cannot always be reduced to zero, it should be possible to reduce them to a level that is ALARP, where they are generally tolerable to society as a whole and to demonstrate that this has been achieved. In industries where there is a possibility of Major Accident Hazards, such as the petroleum exploration and extraction industry, the mechanism for such a demonstration is through the hazard creator's safety case.

The safety case must contain the petroleum undertaking's ALARP demonstration that all risks, including non-Major Accident Hazards are reduced to a level that is ALARP.

The ALARP principle is illustrated in Figure 1. The triangle represents an increasing level of risk from a low risk situation in green at the base of the triangle to a high risk, red region at the top.

The core concepts of the ALARP principle are that there is a level above which risks are generally intolerable and will not be permitted except for exceptional reasons (denoted by upper 'Intolerable Risk' region in Figure 2). Below this upper limit (the 'Upper Tolerability Limit'), the risk is only tolerable if it is ALARP, which means that all 'reasonably practicable' measures must have been identified and implemented. As introduced earlier in Section 2, the term 'reasonably practicable' indicates a narrower range than all physically possible measures: if the cost of a risk reduction measure, whether in terms of money, time or trouble, can be demonstrated to be grossly disproportionate to the risk reduction gained from the measure, taking account of the likelihood and degree of harm presented by that risk, then it may not be required to adopt such a measure.

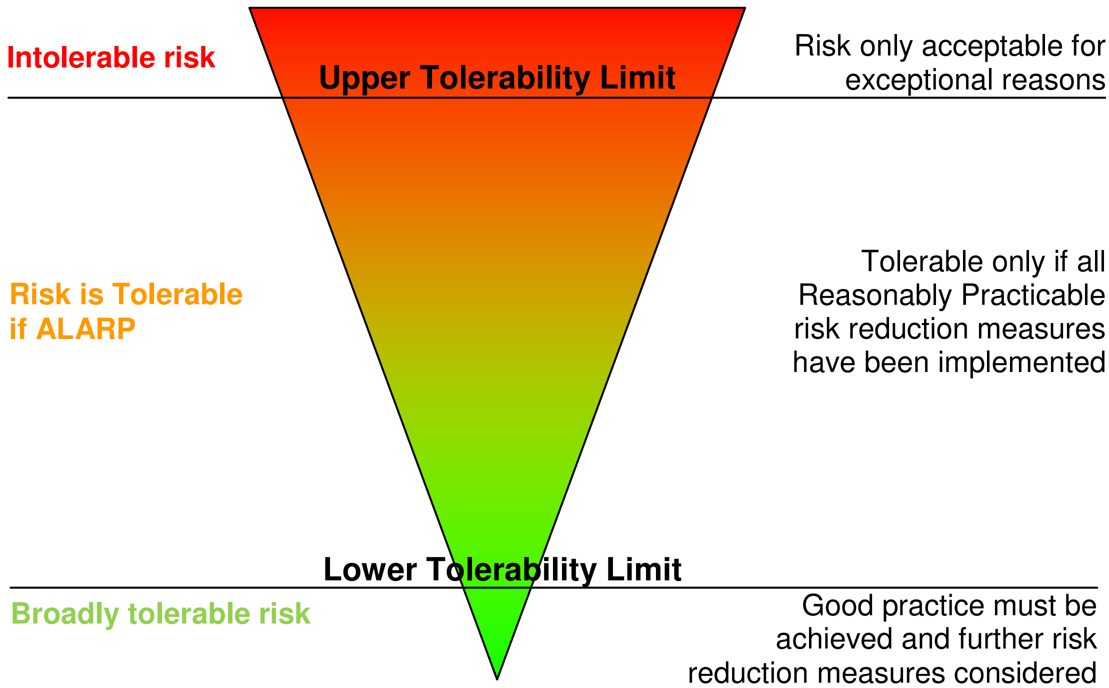

Figure 1: Schematic of the ALARP principle

Figure 1 also illustrates a lower risk limit (the ‘Lower Tolerability Limit’) below which the risks are broadly tolerable to society as a whole and comparable to everyday risks faced by the general public (denoted by the ‘Broadly Tolerable Risk’ region in Figure 1). Below the Lower Tolerability Limit, although risks are generally managed by the application of Good Practice, there is still the requirement on the hazard creator to identify and implement any further reasonably practicable measures. However, in most cases the ALARP demonstration for risks in the ‘broadly tolerable risk’ region will be straightforward.

Between the Upper and Lower Tolerability Limits in Figure 1 is the ‘Tolerable if ALARP’ region. Within this region, a detailed ALARP demonstration is required to provide sufficient evidence that all reasonably practicable measures have been identified and implemented by the hazard creator and, after Good Practice has been achieved, only risk reduction measures where the costs are grossly disproportionate to the safety benefit it provides can be rejected.

Guidance on Risk Tolerability Limits is given in Section 5.

3.2 ALARP Demonstration

The safety case of a petroleum undertaking must demonstrate that all risks are ALARP. Specific requirements for the documented demonstration of ALARP within the different safety cases in the Framework are set out within the *Safety Case Guidelines*. However, there are a number of general requirements for ALARP demonstration across all safety cases under the Framework.

1. The ALARP assessment carried out by petroleum undertakings involves applying an overall hazard management process which incorporates the ALARP principle. The CER's expectations for such a process are outlined in Section 4. Petroleum undertakings should follow this process, or a process that achieves the same objectives. The ALARP assessment, including hazard identification, processes must be described as part of the ALARP demonstration.

2. The total risk that persons are exposed to must be placed in the correct region on the ALARP diagram so as to invoke the correct assessment of a hazard that is affecting those persons. Within the 'Risk is Tolerable if ALARP' region, a detailed ALARP demonstration is required to provide sufficient evidence that all reasonably practicable measures have been identified and implemented by the hazard creator. After Good Practice has been achieved, only risk reduction measures for which the cost is grossly disproportionate to the safety benefit can be rejected. The ALARP demonstration required for risks in the 'Broadly Tolerable Risk' region will often be met by demonstration of adherence with Good Practice.

3. As well as describing the measures that have been implemented, an ALARP demonstration needs to describe those measures that have not been implemented and the reasons for this. This is especially important in lifecycle considerations as circumstances may change such that previously discarded measures might need to be implemented to maintain the risk ALARP.

4. It is expected that there will be persons involved in the ALARP assessment process who are competent in:
   - The operation or design of the plant in relation to the hazard and activity being considered;
   - The risk reduction measures; and
   - Hazard identification, risk and ALARP assessment.

   The hazard identification and ALARP assessment processes should be undertaken by competent professionals and, especially for hazard identification and identification of risk reduction measures, as a team activity.

As stated in Section 1, it is the responsibility of the petroleum undertaking to decide how best to demonstrate that the risks from their activities are ALARP through its safety case. The CER will assess whether it considers the demonstration to be adequate or not given the information provided.

4 ALARP Assessment

4.1 Overview

The ALARP assessment carried out by petroleum undertakings involves applying an overall hazard management process which incorporates the ALARP principle. This section describes CER expectations of such a process, with a schematic overview provided in Figure 2. To achieve a comprehensive and robust ALARP assessment, this process, or a process that achieves the same objectives, should be followed according to:

1. A comprehensive identification of hazards, including specific identification of Major Accident Hazards (Section 4.2);

2. Confirm that where Good Practice is available, it is adopted as a minimum requirement (Section 4.4);

3. Subsequently for any Major Accident Hazard:
   1. A quantitative evaluation of the total risk to persons exposed to such a Major Accident Hazard with specific evaluation of the Major Accident Hazard(s) is carried out
      - In circumstances where the risk of an identified Major Accident Hazard activity cannot be evaluated with sufficient certainty to be reliably compared with Risk Tolerability Limits, or the safety benefit of a risk reduction measure evaluated with sufficient certainty to reliably determine whether its application is required in order for the risk to be ALARP, recourse is made to the precautionary principle (see Section 4.5.7);
      - If the risk of the identified Major Accident Hazard(s) can be evaluated with certainty, the next step in the process is carried out.

   ii. Compare the risk against the Upper Tolerability Limit
      - If the risk is intolerable, it is not permitted except for exceptional reasons and so risk reduction measures must be implemented regardless of whether they are reasonably practicable or not. Once this has been achieved, the assessment carries on as for risks that are initially below the Upper Tolerability Limit.

   iii. Identify any further risk reduction measures that are required to reduce risk to a level that is ALARP (Section 4.5);

   iv. Document and explain all risk reduction measures which are considered by the petroleum undertaking to be 'grossly disproportionate'; and

   v. Implement all identified risk reduction measures which reduce risks to a level that is ALARP.

4. For the non-Major Accident Hazards:
   i. Good Practice, where it is available, is adopted as a minimum requirement;
   ii. Identify any further risk reduction measures which are required to reduce risk to a level that is ALARP; and
   iii. Implement these risk reduction measures.

5. Ensure that all risks continue to be ALARP throughout the lifecycle of the infrastructure/activity (See Section 4.7) by review of the above process.

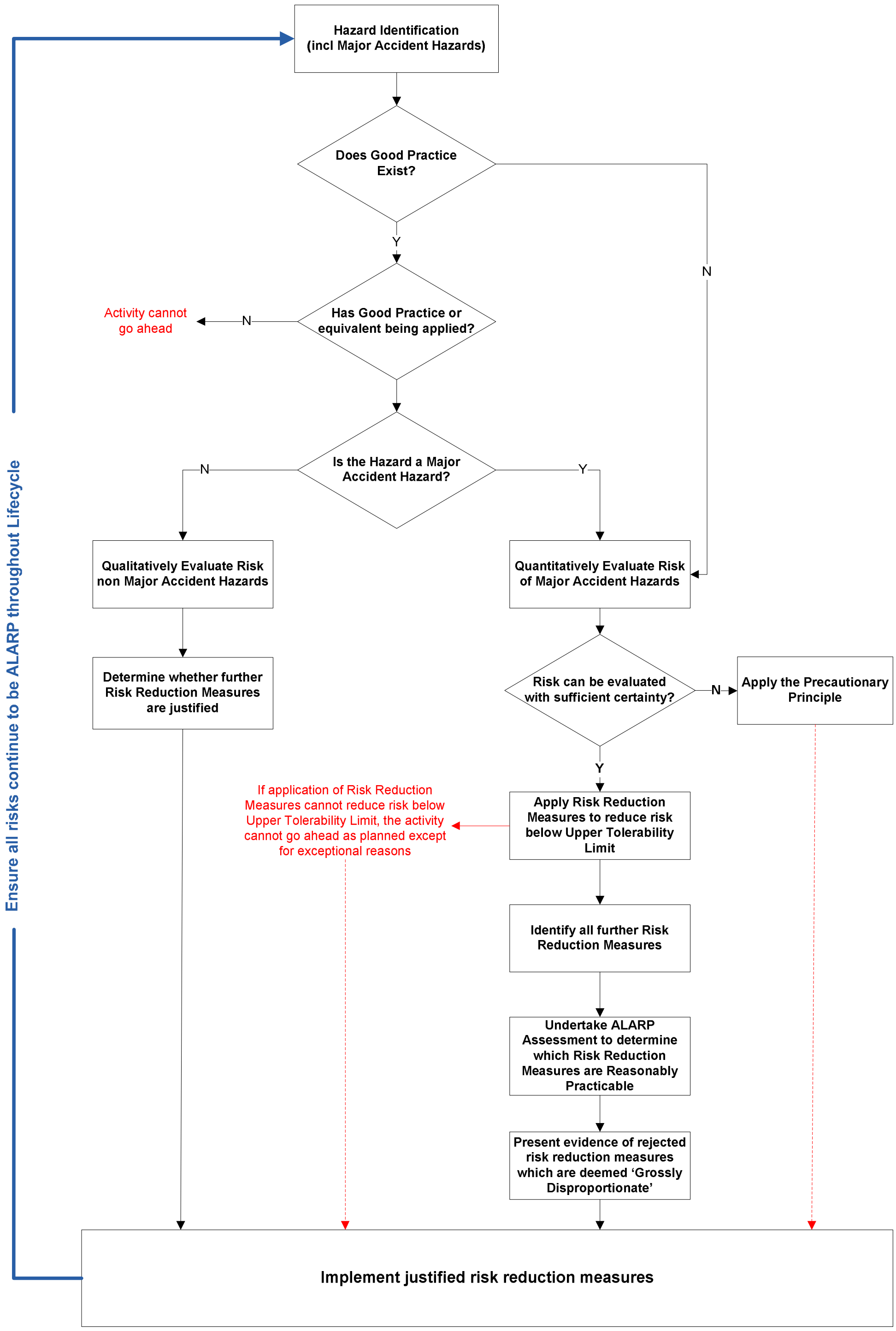

Figure 2: Hazard Management Process incorporating the ALARP Principle

4.2 Hazard and Risk Reduction Measures Identification

4.2.1 Overview

The first stage in the hazard management process is the comprehensive identification of hazards that could have an immediate or long term safety impact to people. The identified hazards are then fed into the ALARP assessment.

Hazard identification is usually a brainstorming process undertaken by a group of skilled and experienced people with knowledge of the particular site, project and/or activities being undertaken. Most hazard identification techniques involve a team approach, since few individuals have expertise on all hazards, and group interactions are more likely to stimulate consideration of hazards that even well-informed individuals might overlook. Operational staff who will be exposed to the hazards can make a valuable contribution to the hazard identification process.

Hazards are diverse, and many different methods are available for hazard identification. The hazard identification methodology should be chosen by the undertaking to match the available information and level of detail that is likely to be required in identification of risk reduction measures. It may be a standard technique, following an established protocol, a modification of one, or a combination of several[15].

Hazard identification requires careful consideration of the ways in which an activity could fail and create a hazard to persons. In all cases the key requirement is for careful consideration of the faults that may occur, which may include:

- **Persons:** Accidental or intended human intervention with unintended consequences;
- **Procedures:** Incorrect procedures leading to an error; and
- **Plant:** Mechanical failure due to factors such as corrosion.

When considering how a hazard may occur, it is not sufficient to just consider the direct past experience of the persons undertaking the hazard identification, or experience of the activity, or site being considered. Every effort must be made to think how failures might occur, identify their causes, consequences and the risk reduction measures that are needed to remove or reduce the risk from these failures. The risk reduction measures can either lower the possibility of the hazard occurring or its consequences, or both.

Hazard identification must be managed in a formal process with accurate recording of the scope and the outcome of the process. Defining the scope of the hazard identification is important as it must be clear that the identification process(es) cover the full activity, otherwise the full range hazards associated with it may not be identified. In addition, the information that is provided to the hazard identification team must be accurate and up-to-date.

---

[15] For source see Reference [9].

4.2.2 Major Accident Hazard Identification

In the hazard identification process, all Major Accident Hazards should be specifically identified and need to be assessed in detail to determine if the risk has been reduced to ALARP. As illustrated in the diagram below, these hazards have a low frequency, but high consequence, making them more difficult to manage, which is why they are a particular focus of the Framework and ALARP assessment.

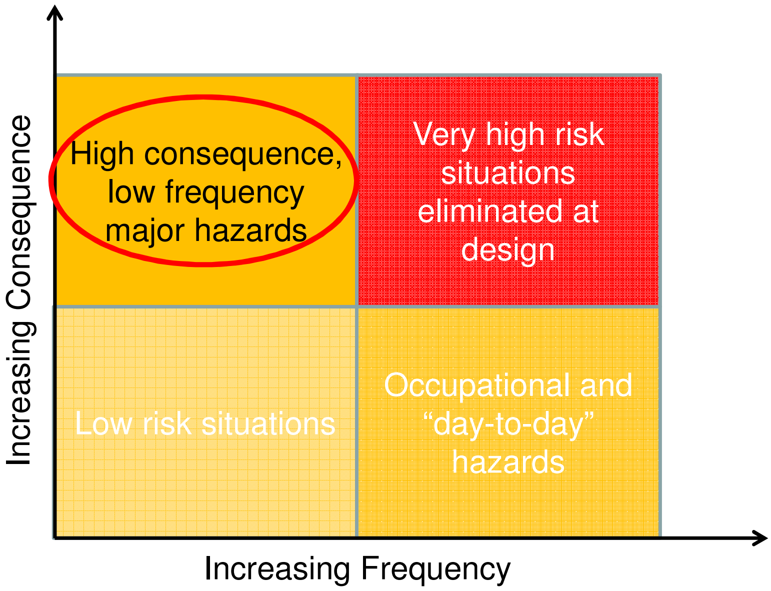

Figure 3: Schematic of different classes of hazard

The hazard identification process becomes more critical as the complexity of the activity increases. For well understood activities with little complexity, the hazards have often already been identified and also the risk reduction measures needed to manage these hazards will be detailed in appropriate codes and standards. A more complex activity will require the hazards associated with all component parts of the activity and, for example, interactions between different equipment items to be identified.

4.2.3 Risk Reduction Measures

After putting in place Good Practice or its equivalent, consideration must be given to whether any further measures are required to reduce risks to a level that is ALARP. Further guidance on this is given in Section 4.5. Potential risk reduction measures should, ideally, be identified at the same time as the hazard identification process.

Risk reduction measures considered may be new, or may be improvements of existing measures already installed either in terms of new equipment, or improved maintenance, or operation.

4.3 Good Practice

For all identified hazards the adoption of Good Practice, where it is available, is the first requirement in the management of the particular hazard. Therefore, the initial stage in determining whether a risk is ALARP is to determine whether at least Good Practice is being met and applied.

4.3.1 What do we mean by Good Practice?

Good Practice is defined to be:

The recognised risk management practices and measures that are used by competent organisations to manage well-understood hazards arising from their activities.

These methods are found in a variety of forms including:

- Guidance or codes of practice from national regulators;
- Standards from standards-making organisations (e.g. NSAI);
- Guidance produced by a body such as a professional institution or trade federation representing an industrial or occupational sector; and
- Lessons learned from previous accidents, not yet incorporated into standards, but identified as an improvement to hazard management.

Good Practice also requires that the management of hazards is considered in a hierarchy, with the fundamental rule being that it is inherently safer to eliminate a hazard entirely than manage its consequences or reduce its frequency. Therefore, the hazard management process must adhere to the following hierarchical approach to risk reduction, with measures at the top of the list considered in preference to those below.

Elimination:	Complete removal of the hazard;
Substitution:	Replacement of one part of a process or design by another that is inherently less hazardous;
Control:	A system that controls a hazard so that the consequences are minimised or removed;
Mitigation:	Action taken or systems put in place to reduce the consequences of the hazard; and
Emergency Response:	Risk reduction through action such as removal of persons from the place of danger or use of personal protective equipment such as smoke hoods, immersion suites and fireproof gloves.

This means that elimination of a hazard should be considered before substitution, control, mitigation, and emergency response in that order.

4.3.2 Applying Good Practice as part of an ALARP Assessment

1. Good Practice in the management of hazards should be considered in the hierarchy set out in Section 4.3.1.

2. Good Practice evolves as knowledge and experience increases over time, and it is **current** Good Practice that forms the basis of an ALARP demonstration. This affects the assessment of ALARP in three ways:
   a. Codes and standards that are current and relevant to the activity being considered must be used for new designs, or activities;
   b. If there is a choice of codes, a justification as to why the selected code is the most appropriate; and
   c. If a code or standard changes such that an existing activity does not meet the current code and there is a safety implication, there is a need to assess whether it is reasonably practicable to make changes to meet the new code.

3. In assessing Good Practice, it is important to consider whether all aspects of an activity are covered by Good Practice. It may be possible for each individual aspect of an activity to be covered by a prescriptive code that defines Good Practice, but no guidance given for the sum of all of them. In this case, an ALARP assessment must be undertaken for the totality of the activities.

4. If Good Practice is defined by a particular code, Good Practice can either be achieved by adherence to the code, or implementing measures that reduce the risk from the hazard managed by the code to at least the same degree as that achieved by code. Where Good Practice exists, activities that do not meet it, or an equivalent, will not be approved by the CER.

5. Some codes and standards are risk-based and therefore do not give an absolute test of Good Practice. However the methodology in the code, or standard should be followed as long as it complies with the remainder of this guidance.

4.4 *Evaluation of Risks against Tolerability Levels*

4.4.1 Assessment Process

The risks from all Major Accident Hazards must be evaluated using quantitative risk assessment[16] to allow explicit comparison with the Risk Tolerability Limits. Risks must be placed in the correct region on the ALARP diagram to enable the appropriate assessment. For public risk, all Major Accident Hazard sources must be included in the assessment against the Risk Tolerability Limits, which means that if two or more designated petroleum activities can affect the same public population, the total risk from these sources should be evaluated and compared against the Risk Tolerability Limits. For risk to workers, non-major hazards (e.g. occupational hazards) have to be included in addition to all Major Accident Hazard sources.

If the risk is intolerable, risk reduction measures must be implemented, regardless of whether they are reasonably practicable, until the risk drops below the Upper Tolerability Limit, except for exceptional reasons.

If the risk is tolerable if ALARP, a detailed ALARP demonstration is required to provide sufficient evidence that all reasonably practicable measures have been identified and implemented by the hazard creator and only measures where the costs are grossly disproportionate to the safety benefit it provides can be rejected.

A similar risk evaluation process is not required for persons that are only exposed to non-Major Accident Hazards. It is for the petroleum undertaking to show that the risk does not threaten the Upper Tolerability Limit by, for example, showing adherence to good practice and direct reference to historical data for the activity. In this case, or if the risk is broadly tolerable, the ALARP demonstration is not as onerous and can follow the guidance for the assessment of broadly acceptable risks given in Section 4.4.3.

4.4.2 Assessment Guidance

For some activities with the potential for Major Accident Hazards, the risk may be well understood, for example, a pipeline built to a specific code for which the maximum risk (of building to the limit of the code) is known. If this is known to be either in the Broadly Tolerable Risk region, or in the Tolerable if ALARP region, this calculation does not need to be repeated to show this for the particular pipeline, as long as it meets all aspects of the relevant code. However, it may be the case that a quantitative evaluation of the risk is still required to assess whether further risk reduction measures should be implemented.

If the risk of the activity cannot be evaluated with sufficient certainty to reliably compare with the Risk Tolerability Limits, or the safety benefit of a risk reduction measure evaluated with sufficient certainty to reliably determine whether its application is required in order for the risk to be ALARP, recourse is made to the precautionary principle (see Section 4.6).

To assess tolerability for a particular activity, the evaluation needs to encompass the *entire*

[16] See Section 4.5.5.1 for high level guidance on quantitative risk assessment

risk that persons are exposed to. In many cases this will be the same as the risk from the activity under consideration, but in some cases (for example, where persons may be exposed to risks from a variety of activities from different or adjacent sources), these will need to be aggregated to determine the total risk exposure. This is a similar scenario to one where a large number of different hazards and potential accidents exist and the cumulative risk may be above the Upper Tolerability Limit even if the risk arising from each is low.

For a situation where an activity is itself low risk, but where the total risk to the person from all sources is not necessarily low (for example carrying out domestic maintenance in the accommodation of an offshore platform), the total risk will need to be assessed using Quantitative Risk Assessment (QRA), but the determination of risk reduction measures for the simple task (domestic maintenance) will itself be straightforward and can follow the guidance for broadly acceptable risks below. However, there is the potential for the simple task to be affected by the wider activities in progress, so the hazard identification undertaken as the foundation of the ALARP demonstration must be comprehensive and robust.

4.4.3 Broadly Tolerable Risk

The risk from a Designated Activity for which the risk is below the Lower Tolerability Limit and for which Good Practice has been implemented will generally achieve the reduction of risk to a level that is ALARP. In this case, the petroleum undertaking still needs to be vigilant in considering whether Good Practice is improving and relevant, or whether there are any additional hazards present which need to be considered. This means that there may be circumstances where further risk reduction measures should be identified and considered. In considering the measures required to be in place to reduce risks falling within this category to a level that is ALARP, the assessment of what may be grossly disproportionate in relation to the risk reduction measures proposed and the safety benefits achieved will take account of the level of risk identified. This does not mean that a petroleum undertaking should not implement measures that are of low cost and provide a clear risk reduction. The petroleum undertaking still has to go through a process of hazard identification and risk assessment in order to carry out this process.

Due to the relatively low risk associated with broadly tolerable risks, it is unlikely that the more complex assessment techniques in section 4.5 will be required as simpler techniques should provide confidence of whether a particular risk reduction measure needs to be implemented or not. It is likely that a simple technique such as engineering judgement, qualitative risk assessment or a simplified, but conservative, quantitative analysis can be used to assess the risks and determine appropriate risk reduction measure. Section 4.5 provides further guidance of how it may be shown that the measures proposed have reduced risks to a level that is ALARP.

If there is no Good Practice in relation to the hazard, or activity, the risk must be evaluated as per the assessment for Major Accident Hazards.

4.5 Determining what is Reasonably Practicable

4.5.1 Introduction

The following sections provide guidance on how a Petroleum Undertaking may determine and demonstrate whether a risk reduction measure needs to be implemented in order for the risk to be ALARP and what may be considered 'reasonably practicable' in this context. The approach to be used will vary according to the hazard, risks and risk reduction measure being considered.

The approaches that are described are:

- **Engineering judgement**, whereby previous applicable experience is used in conjunction with other tools;
- **Qualitative risk assessment**, in which frequency and severity are qualitatively determined;
- **Semi-quantitative risk assessment**, in which frequency and severity are approximately quantified within ranges; and
- **Quantitative risk assessment**, in which full quantification occurs.

The list of approaches form a hierarchy with the top two approaches generally being more amenable to decisions where the risk implications of the decision on whether to implement the risk reduction measure are relatively low, the situation is well-understood, or the risk is broadly tolerable as described in Section 4.4.3. These two approaches are often used first in an assessment of reasonable practicability. However, if, after having applied them, the measure is not implemented, but the result is uncertain, a more sophisticated methodology should be used to assess reasonable practicability.

Only the semi-quantitative risk assessment and quantitative risk assessment techniques can directly compare the cost of a risk reduction measure to its safety benefit and so are more amenable to the assessment of risk in the tolerable if ALARP region and of engineering issues during any stage of the lifecycle of petroleum infrastructure. However, even if the overall risk is in the Tolerable if ALARP region, then, a low risk hazard that contributes a small proportion of the overall risk can be assessed by any technique as described this section.

Figure 4 on the following page outlines the above hierarchy, with the overarching requirement to meet Good Practice.

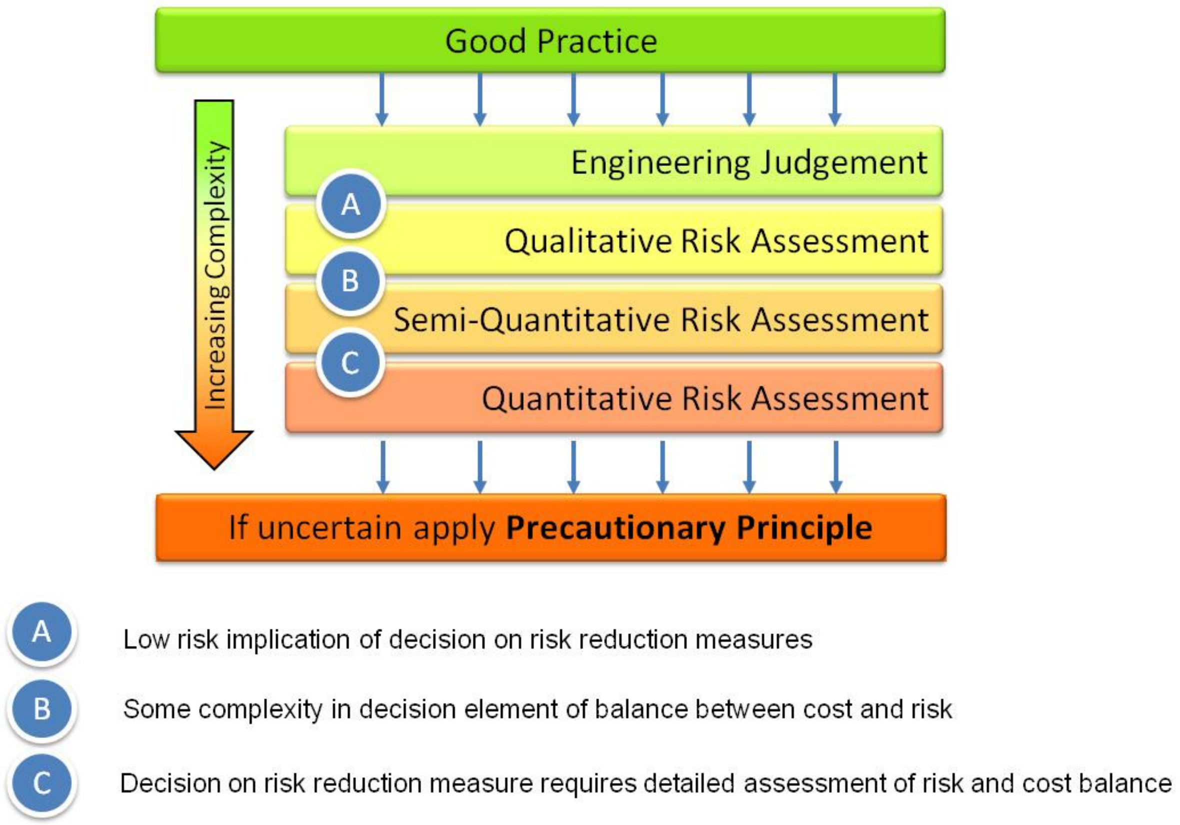

Figure 4: Schematic of methods to determine reasonable practicability

Petroleum undertakings can determine the reasonable practicability of a risk reduction measure using any of the above methods. However the correct method for a particular decision must be chosen such that there is sufficient certainty in the analysis to justify the decision.

If none of the decision approaches listed above gives sufficient certainty that the risk of the activity is ALARP without implementation of a particular risk reduction measure, recourse is made to the precautionary principle.

Guidance on each of the above approaches in assessing reasonable practicability is set out below.

4.5.2 Engineering Judgement

A particular aspect of a proposed activity may be such that good practice cannot be directly applied, or does not exist. For example, the precise location of escape routes on an offshore platform is not defined in good practice. There could also be situations where there are variables or complexities that do not allow any clear definition of good practice.

In these circumstances, the first recourse can be to conduct engineering analysis and assessment, without using risk assessment techniques, in order to assess potential means of managing the hazards. This would generally require a good understanding of the mechanisms that might lead to the realisation of the hazard and the potential interactions due to any complexities.

Engineering judgement would be used in the selection of analysis and assessment methods and in interpreting the results and it relies on experience of similar situations and knowledge of the hazards and associated risk reduction measures. The objective would be to demonstrate that the hazards are managed in a way that is ALARP, possibly by extension of current good practice into the particular circumstances being considered.

As activities become more complex, recourse to engineering judgement may not be sufficient or possible. While elements of any activity are likely to be covered by codes and standards, the combination of these elements can be complex and the nature of the hazards outside the experience of the persons whose engineering judgement is being sought. Engineering judgement cannot then be relied upon and qualitative, semi-quantitative or quantitative risk assessment should be used.

4.5.3 Qualitative Risk Analysis

4.5.3.1 The Technique

Qualitative risk analysis is a method of ranking risks without assigning any absolute values to the consequence, frequency, or risk. Consequence and frequency are typically assigned into bands described as very low, low, medium, or high. The overall risk then varies from very high (when both consequence and probability are high) to very low (when both are low). Very high risks are then deemed to be unacceptable, very low risks broadly acceptable and in-between the risk must be reduced in order for it to be ALARP.

The technique splits frequency, consequence and risk into a relatively small number of discrete bands, which are not assigned numerical values, and so the accuracy of an assessment is limited and it should not be used to make many of the decisions that are key to an ALARP demonstration regarding Major Accident Hazards.

4.5.3.2 Assessing Risk Reduction Measures

The technique is most suitable for risk assessment of operational tasks in connection with the General Duty to maintain non Major Accident Hazard risks ALARP. However, even in this case, the qualitative nature of the tool and coarseness of assessment means that it can only be used to assess well-understood hazards with well-understood safeguards.

4.5.4 Semi-quantitative Risk Analysis

4.5.4.1 The Technique

Semi-quantitative risk analysis is similar to qualitative risk analysis, but with the addition of numerical bandings of consequence and frequency, which are combined together to give a risk banding. There are a number of standard methodologies for this approach, including a risk matrix and layers of protection analysis. Each of these techniques uses numerical bands (often orders of magnitude) to describe frequencies and consequences associated with the hazard being considered and defines one of a number of risk bands to each combination of frequency and consequence. It provides a better basis for assessing risk reduction measures than qualitative risk analysis, but is less accurate than quantitative risk assessment, where more detailed quantification is carried out.

For semi-quantitative risk analysis to be used as part of an ALARP demonstration, the numerical bands that are used in the technique must be defined. Possible ways to quantify the bands for the frequency side of the risk assessment include bands for events likely to occur:

- Every N years, where N varies between the bands;
- Once in the site's lifetime; or
- Once each year in the worldwide oil and gas industry.

Whatever bandings are chosen they must be well-defined and not open to interpretation by the persons undertaking the risk assessment.

In order to be used successfully, the frequency, consequence and risk banding must have sufficient resolution to allow for an ALARP demonstration for the full range of scenarios intended to be covered by the technique. The frequency of a Major Accident Hazard should be many orders of magnitude less than the frequency of a lost time injury and if both types of hazard are covered by the same matrix, it is clear that multiple frequency bandings will be required. It is unlikely that the technique can be used successfully if a frequency band covers more than an order of magnitude in terms of years between events.

The definition of the risk bandings used must also be well thought through and consistent such that a particular risk reduction measure is not favoured solely due to a particular choice of risk banding resulting from a combination of frequency and consequence.

In assessing the risks using this technique, the potential for a number of different scenarios to arise from the same hazard should be considered. The most likely outcome rarely corresponds to the highest consequence outcome and therefore, before the assessment is undertaken, it may not be obvious which the highest risk scenario is. In this case, a number of scenarios must be assessed in order to find the highest risk. However, the assessment must avoid the potential for "salami slicing" of the risk picture, whereby too many scenarios are used with the risk from each one being low, but the overall risk being higher. If a large number of scenarios (say greater than six) are needed to either well-define the highest risk, highest frequency event or differentiate between the cases being considered (with and without a risk reduction measure in place), then the technique is at the limits of its applicability and it points towards the need for a more sophisticated quantitative risk assessment.

4.5.4.2 Assessing Risk Reduction Measures

To use semi-quantitative risk assessment to assess whether a single risk reduction measure needs to be implemented for the risk to be ALARP, calibration of the technique needs to have been undertaken beforehand such that it is known the cost of a risk reduction measure that constitutes gross disproportion for a particular change in risk.

The approach can also be used to determine which of two risk reduction measures should be implemented, where it is physically not possible to implement them both, for the risk to be ALARP if the difference in risk reduction between them clearly favours the one with a lower cost (i.e. the more expensive measure actually gives less risk reduction). If the measure providing a greater risk reduction also costs more, the comparison may not be as clear and if insufficient certainty can be gained in the result for the semi-quantitative assessment, quantitative risk assessment may be needed to determine which one to implement to achieve risks ALARP.

The introduction of some quantification in assessing ALARP means that more complex scenarios can be assessed and the decision basis is more transparent. If qualitative risk analysis is unable to distinguish the risk difference between two scenarios (generally one with and one without a particular risk reduction measure), semi-quantitative risk analysis may be able to do this. If semi-quantitative risk analysis still cannot differentiate between them, then quantitative risk analysis may be used to show the difference. It can be appropriate to use a semi-quantitative technique in the assessment of specific risks associated with a single hazardous event, or as a screening tool to identify those hazards that should be considered for more detailed analysis. However, where the potential consequences are more severe, or there is a need to assess the combined risk from many hazards, then semi-quantitative risk analysis is unlikely to be appropriate.

4.5.5 Quantitative Risk Analysis and Cost Benefit Analysis

Quantitative Risk Analysis (QRA) can be used to calculate a numerical value for risk, which can be converted into a cost that can be directly compared to the cost of a risk reduction measure to assess whether the measure should be implemented to achieve ALARP. Guidance for these steps is given below.

4.5.5.1 Quantitative Risk Assessment

In a quantitative risk assessment, the frequency and consequence of a hazard are assessed in detail in order to ascribe numerical values to each, allowing a numerical value of risk to be calculated. QRA will typically consider the development of any hazardous scenario in detail, with the frequency and consequences of many outcomes being evaluated. It therefore provides a much more detailed picture of the associated risks allowing for the difference in safety benefits between different risk reduction measures to be assessed more accurately.

The level of detail required in the assessment will vary between hazards. Risks that do not contribute significantly to the overall risk total and for which decisions on risk reduction measure are not based on QRA may be assessed more conservatively than higher risk hazards and do not require as much detail in the assessment. The risk assessment should be commensurate with the hazard and so, for example for occupational hazards, may just refer to generic data for the broad type of activity being undertaken.

To use QRA to determine whether a measure should be implemented to achieve ALARP, the QRA process must be rigorous, exhaustive and transparent. As far as possible, the frequency of the event should be calculated from a basis of historical data and modified, or combined with other probabilistic data related to the actual situation being considered. The consequences of each potential outcome are then analysed, often using some form of mathematical model, to determine the risks associated with the event.

The quality of the modelling and the input data will affect the accuracy of the numerical estimate and so the uncertainties associated with the assessment must always be borne in mind when using QRA in hazard management decisions. The use of numerical estimates of risk, by themselves, can be misleading and if not used correctly may result in incorrect decisions. To use QRA in the ALARP decision process, it must encompass engineering and operational understanding of the hazard being modelled.

Where significant decisions are required with regard to major hazards, the QRA must be subject to *sensitivity analysis* to gauge the potential for plausible changes in basic assumptions, or, for example, a foreseeable change in working pattern, to invalidate the conclusions and decisions taken from the risk analysis.

Whilst QRA will not form the only argument in an ALARP demonstration, it is required for activities that have the potential for Major Accident Hazards as it is necessary to compare risk levels with quantified Risk Tolerability Limits and to inform significant decisions with regard to Major Accident Hazards. QRA is also subject to uncertainties and undertakings will be expected to address this in any quantification process to ensure that appropriate conservatisms are adopted.

4.5.5.2 Cost Benefit Analysis

Cost benefit analysis (CBA) is the numerical assessment of the cost of implementing a particular risk reduction measure, such as a design change or modification and the comparison with the likely reduction in fatalities that this would be expected to achieve.

The way that this is done is to:

(1) Calculate the Implied Cost of Averting a Fatality (ICAF) for the risk reduction measure, which is the cost divided by the risk reduction and

(2) Compare this to a Defined ICAF criterion.

A risk reduction measure will then be reasonably practicable to implement unless the calculated ICAF is grossly disproportionate to the Defined ICAF. Lower ICAF values, which are less likely to be grossly disproportionate, occur because of lower costs, or greater risk reduction.

In order for CBA to be used as part of the argument as to why the implementation cost of a particular risk reduction measure is not reasonably practicable due to it being grossly disproportionate to the safety benefit it delivers, a Defined ICAF value of at least **€2,400,000** is advised (at 2013 prices). An explanation as to why this figure is advised is given in Appendix I. However, in using this figure a range of factors, including uncertainty, need to be taken into account in the decision making process. Ultimately, it is for the Petroleum Undertaking to determine the measures required to reduce the risk to a level that is ALARP and that a decision not to implement a particular measure on the grounds that the cost is grossly disproportionate to the safety benefits it would achieve (and therefore not reasonably practicable), takes account of all relevant factors and circumstances.

4.5.5.3 Gross Disproportion Factor

In order for CBA to be used as part of the argument as to why the implementation cost of a risk reduction measure is grossly disproportionate to the safety benefit it delivers, a Gross Disproportion Factor must be shown between the cost and the safety benefit. A factor of at least ten is advised and a robust justification will be required for any lower value. An explanation of why this figure is advised is given in Appendix II. Thus, if the difference between the cost of the risk reduction measure and its safety benefit is less than a factor of ten, gross disproportion is not normally shown and the risk reduction measure will require to be implemented. It is important to recall, however, that the test of whether a measure is grossly disproportionate to the cost of the risk reduction measure will require to be considered for each circumstance in which a petroleum undertaking asserts that it is not reasonably practicable for a particular measure to be implemented, and will include assessment of the associated risks and the safety benefit provided by the measure in question for the particular circumstances in which it is being considered.

4.5.6 Guidance on General Issues relevant to assessing Reasonable Practicability

4.5.6.1 Range of Consequences to be Considered

If a hazard is realised, the consequences that develop will vary depending on the details of the event, environmental conditions and the reaction of persons and safety systems. Due to the large number of outcomes, it is appropriate to model a reduced range of consequences in the ALARP assessment and if this is done, consequences that at least cover the worst-case and most likely events need to be modelled ensuring the full frequency of the event is accounted for.

Alternatively, just the worst-case consequences could be modelled assuming that every time the hazards is realised it leads to this worst-case. Being a conservative assessment, this approach will be more likely to lead to the conclusion that a risk reduction measure should not be implemented.

Assessments should adequately justify that the selected scenarios conservatively represent the spectrum of scenarios that could occur.

4.5.6.2 Cost of the Risk Reduction Measure

The cost of the measure, against which the risk reduction is being compared, should be restricted to those costs that are solely required for the measure. Realistic values should be used for the costs of the measure so that it is not over engineered to derive a large cost and thus distort the comparison to ensure a conclusion that it would be grossly disproportionate to implement.

If the cost of implementing a risk reduction measure is primarily lost production, the ALARP assessment should be undertaken for the two cases where lost production is and is not accounted for. If the decision is dependent on the lost production (i.e. the risk reduction measure would be installed without considering this cost), a highly robust and thorough argument as to why the measure could not be installed while losing less production (e.g. at a shutdown) will be required if the measure is to be rejected.

If the lost production is actually deferred production (i.e. the life of the equipment is based on operating rather than calendar time), then the lost production should only take account of lost monetary interest on the lost production plus allowance for operational costs during the implementation time, or potential increase in operational costs at the end of life.

If shortly after a design is frozen, or constructed, a risk reduction measure is identified that normally would have been implemented as part of a good design process, but has not been, it would normally be expected that the measure, or one that provides a similar risk reduction, is implemented as soon as is practicable. An argument of grossly disproportionate correction costs cannot be used to justify an incorrect design.

4.5.6.3 Remaining Lifetime

In determining whether it is reasonably practicable to implement a particular risk reduction measure, the remaining lifetime of the petroleum infrastructure is relevant in the analysis. This is immediately apparent in a cost benefit analysis where the cost of the risk reduction measure is mainly a capital cost since the total risk reduction will rise as the remaining lifetime increases whilst the costs remain constant. Thus a risk reduction measure will generally increase in reasonable practicability as the Petroleum Infrastructure lifetime increases.

If the cost of a risk reduction measure is assessed to be in gross disproportion to the safety benefit it provides and it is not implemented because of a short remaining lifetime, it is expected that supporting analysis will be carried out for a number of different remaining lifetimes due to the uncertainty in such a figure. The justification for a non-implementation decision that is dependent on the short lifetime assumption would have to be extremely robust.

Over the lifecycle, improvements in Good Practice may occur, which if implemented would give reduced risks. It is recognised that the cost of modifying an existing activity may be grossly disproportionate to the safety benefit and so an ALARP assessment is appropriate to inform the decision on whether to implement new risk reduction measures to meet Good Practice. In judging whether it is reasonably practicable to implement the risk reduction measure, it is appropriate to consider the remaining life of the petroleum infrastructure, although any ALARP assessment where a risk reduction measure is not implemented due to a short remaining life will have to be robust and also subject to sensitivity analysis around the remaining life.

4.5.6.4 Differing Results

The situation where a petroleum undertaking is evaluating the results of one assessment tool (of those described above) against the opposing results of another should not be allowed to arise. In an example where the use of qualitative risk analysis concludes that a risk reduction measure is not required, but a quantitative risk assessment concludes that it is, if the techniques have been applied correctly, the conclusion is that the qualitative risk analysis was not a sophisticated enough technique to assess the risk reduction measure in question. The relative results and merits of the two approaches should not be balanced against each other – the petroleum undertaking should assess which approach gives a result with sufficient certainty on which to base a conclusion.

4.5.6.5 Avoidance of Reverse ALARP

An argument could be constructed that, for a reason such as the short remaining lifetime, the re-instatement cost of a previously functioning risk reduction measure is grossly disproportionate to the safety benefit that it achieves. This is commonly called *reverse ALARP*. In this case, the test of Good Practice must still be met and, since the risk reduction measure was initially installed, it is Good Practice to reinstall or repair it. Reverse ALARP arguments will not be accepted in an ALARP demonstration.

4.5.7 The Precautionary Principle

While there can be an element of uncertainty in risk assessment for a petroleum activity the approach adopted should be such that there is sufficient certainty that the results are at least representative, if not conservative, for the activities being considered. It is for the petroleum undertaking to demonstrate this in their analysis. Where there is reason to believe that serious danger could exist, but the scientific evidence is insufficient, inconclusive or uncertain regarding the risk, then the petroleum undertaking is expected to apply the precautionary principle. In applying the precautionary principle, it is expected that a cautious approach is adopted to hazard management, commensurate with the level of uncertainty in the assessment and the level of danger believed to be possible.

If there is a high degree of uncertainty and reason to believe that potentially serious negative consequences may arise, the petroleum undertaking is expected to conduct a structured scientific evaluation of the risk to safety that is as complete as possible, in order to select the most appropriate course of action to manage the risks generated by their proposed activities. The analysis needs to include an assessment of the scientific uncertainties and a description of the hypotheses used to compensate for the lack of scientific or statistical data and where appropriate, proposals for advancing the scientific understanding such that the risk can be better understood. While CBA may be applied to the management of risks, assumptions made in the assessment about the frequencies and consequences are expected to err on the side of caution and so seek to avoid harmful effects. While the approach adopted is expected to be proportionate and consistent, under the precautionary principle, protection of safety is expected to take precedence over economic considerations. The onus is on the petroleum undertaking, as the hazard creator, to provide a robust case to demonstrate an acceptable level of safety in the face of significant uncertainty. Where risks presented by petroleum activities are well understood, and the supporting scientific evidence is robust, recourse to the precautionary principle is not necessary. It is the responsibility of the petroleum undertaking to decide how best to demonstrate that the risk from their activities is ALARP. The CER will assess whether they consider the demonstration to be adequate or not given the full array of information provided.

It is possible that the application of the precautionary principle will result in the implementation of control measures that may appear to be grossly disproportionate. However, in the circumstances in which the precautionary principle is invoked, the uncertainty associated with the risk assessment means that it cannot be proven with sufficient certainty that the cost of the measure is in disproportion to the safety benefit it brings. The hazards that are assessed in this process in order to determine the risks should not be hypothetical hazards that have no evidence that they may occur. The hazards that are considered should be based on a worst-case scenario that can be realised.

4.6 Risk Reduction Measure Implementation and Lifecycle

All measures which have been assessed as being required to reduce risks to a level that is ALARP should be implemented.

There is a General Duty on petroleum undertakings to carry out their activities in a manner that makes any risk to safety ALARP and that any petroleum infrastructure is designed, constructed, installed, maintained, modified, operated and decommissioned in a manner that reduces risk to be ALARP. This requirement reinforces the need for the undertaking to consider ALARP at all stages of the lifecycle of petroleum infrastructure.

The need to ensure that the risk is ALARP must be considered at the beginning of the design process for an activity, namely during the concept selection stage. This requirement is important because, early in the design process, decisions can fundamentally influence the risks. The concept and early design stages offer an opportunity to eliminate hazards and to make the petroleum infrastructure inherently safer. It is therefore important that the ALARP demonstration is considered at the concept stage of any petroleum infrastructure and continues throughout design and operations.

Figure 5 illustrates the impact that different risk reduction techniques can have at different stages of the lifecycle. The diagram is split into three bands. In each band the width of each risk reduction measure is a representation of the impact it can have on the overall risk.

The left-hand band shows that elimination and substitution are the most important risk reduction measures at the concept stage and that they apply more to this stage of the design than any other. Eliminating hazards and ensuring inherent safety principles are applied is vital at the concept and design stages. During the operational stage, the emphasis on further risk reduction measures is towards control, mitigation and emergency response, as the fundamentals of the design cannot usually be changed meaning that hazards cannot usually be eliminated.

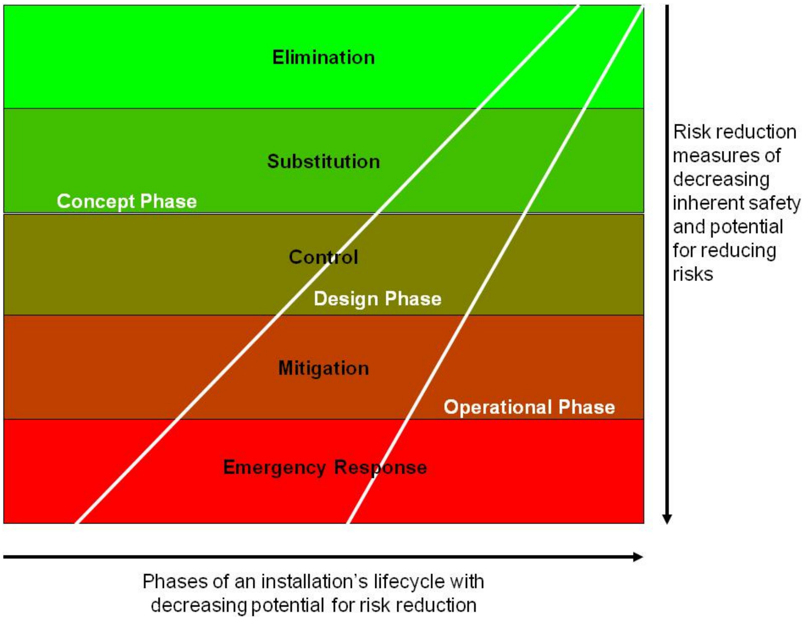

Figure 5: Risk reduction measures at different stages of the lifecycle.

As an activity progresses there is no guarantee that the risks will remain ALARP. This is due to a number of factors including changes to the definition of Good Practice (also see sections 4.3 and 4.5.6), changes that may make the activity more hazardous, or changes in technology that allow for better hazard assessment or control of the hazard. An undertaking must also strive for continuous improvement, which involves identifying opportunities to improve risk reduction measures, learn from mistakes, learn from other operations and always consider how things could be done better.

Reducing risks to ALARP must be considered and re-considered throughout the lifecycle from early in the design stage through to the operational stage. It is incumbent on the hazard creator to continually review whether the risk remains ALARP.

5 Risk Tolerability Limits

5.1 Introduction

The ALARP principle requires that Risk Tolerability Limits are defined. This section provides guidance on these limits for both workers and members of the public as follows:

- Individual risk per annum (for workers and members of the public); and
- Societal risk per annum (in the form of an FN curve for members of the public).

The values which have been adopted for the risk limits are consistent with current practices in Ireland and internationally. While the limits provide guidance, petroleum undertakings are expected to abide by the limits.

5.2 Individual Risk

Individual risk is the risk to a single person. The number of people affected by an accident does not influence individual risk.

In order for a hazardous activity to be permitted, society must allow people to be exposed to some individual risk. Persons at work benefit directly from the activity and are aware of the associated hazards, whereas this generally does not apply to the public. Therefore, different individual risk limits are set for workers and the general public as set out in Table 1. A justification on why these figures are advised is given in Appendix D.

	Upper Tolerability Limit	Lower Tolerability Limit
Worker	10^{-3}	10^{-6}
Public	10^{-4}	10^{-6}

Table 1: Individual risk limits for workers and the general public

The limits apply to an individual risk metric that takes account of the occupancy level of persons exposed to the hazard. For workers, individual risk should be calculated taking account of their normal work pattern, although a risk that is below the Upper Tolerability Limit solely because of a work pattern that is not Good Practice will not be accepted.

Individual risk for the general public should be calculated on the basis of a hypothetical person occupying the nearest normally occupied building to an onshore site that is carrying out designated activities or pipeline and with means of escape. The occupancy level of this hypothetical person should be taken as a 9:1 ratio for time spent inside the building against time spent outside.

In addition, individual risk calculations should take account of the risks presented by other Designated Activities and other sites that have the potential for major accident hazards in the vicinity, as the tolerability levels apply to the total risk, not just the risk from the hazard being considered.

5.3 *Societal Risk*

Major accidents have the potential to affect large numbers of people and there is a societal aversion to events that cause a large number of fatalities. Therefore, societal risk limits are defined to express a limit for the cumulative risk to groups of people who might be affected by a hazard.

Societal risk is commonly represented by a *frequency number (FN) curve,* which is a plot of cumulative frequency (likelihood) of all events leading to N or more fatalities. FN curves are typically plotted on a log-log scale since the frequency and number of fatalities can range over several orders of magnitude.

The FN curves that define the Tolerability Limits are shown in Figure 6, where the terms have the same interpretation as in Figure 1, with defining points shown in Table 2. The FN curve that defines the upper tolerability limit has a slope of -1 and has a frequency of 2×10^{-5} for 50 fatalities or more. The FN curve that defines the lower tolerability limit is two orders of magnitude below the higher limit.

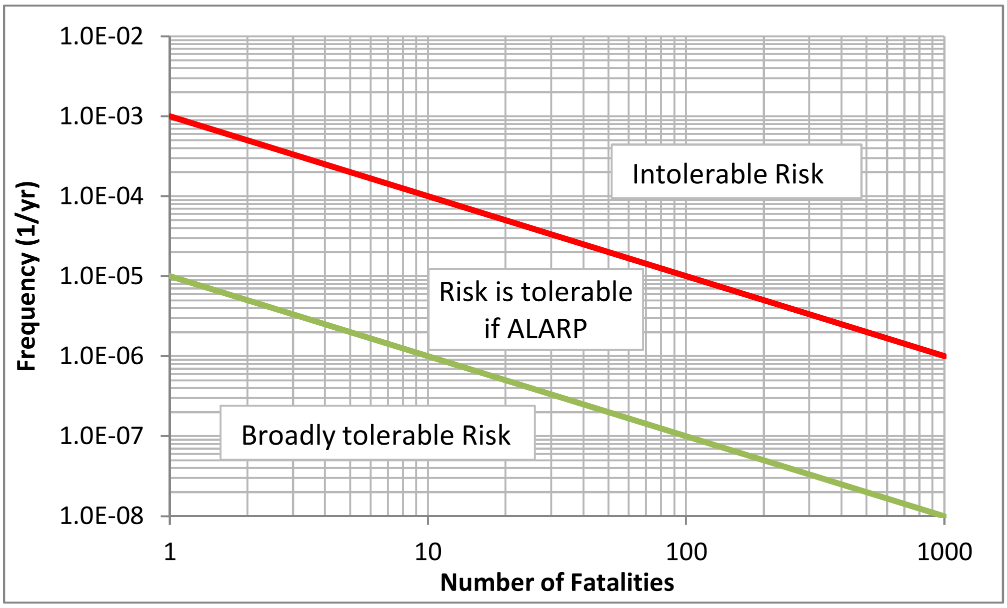

Figure 6: FN curve showing the tolerability limits

No. of Fatalities	Upper Tolerability Limit	Lower Tolerability Limit
1	1×10^{-3}	1×10^{-5}
10	1×10^{-4}	1×10^{-6}
50	2×10^{-5}	2×10^{-7}
100	1×10^{-5}	1×10^{-7}
1000	1×10^{-6}	1×10^{-8}

Table 2: Societal risk tolerability limits

The societal Risk Tolerability Levels[17] only apply to members of the public and the workforce should not be included in this assessment.

[17] A justification on why these figures are advised is given in Appendix D.

Appendix A References

[1] *Decision Paper on the High Level Design of the Petroleum Safety Framework*, (CER/12/062) CER, 2012.
This paper is available at
http://www.cer.ie/en/petroleum-safety-decision-documents.aspx?article=377f83c7-7b02-4d69-b8b4-e7efea77f2e7

[2] *Project Appraisal Guidelines Appendix 6 National Parameter Values Sheets*, NRA, 2011.
This paper is available at
http://www.nra.ie/Publications/DownloadableDocumentation/ProjectAppraisal/file,14148,en.pdf

[3] *HSE Hazardous Installations Directorate (HIDs) Approach to As Low As Reasonably Practicable (ALARP) Decisions*, HSE, 2008.
This paper is available at
http://www.hse.gov.uk/foi/internalops/hid_circs/permissioning/spc_perm_39.htm

[4] *Policy & Approach of the Health & Safety Authority to COMAH Risk-based Land-use Planning*, HSA, 2010.
This paper is available at
http://www.hsa.ie/eng/Your_Industry/Chemicals/Control_of_Major_Accident_Hazards/Approach_to_LUP_under_Comah_Regs.pdf

[5] *Guidance for Risk Assessment of Offshore Installations (Offshore Information Sheet No. 3/2006)*, HSE, 2006.
This paper is available at http://www.hse.gov.uk/offshore/sheet32006.pdf

[6] *Reducing Risks, Protecting People (R2P2). HSE's Decision Making Process*, HSE, 2001.
This report is available at http://www.hse.gov.uk/risk/theory/r2p2.pdf

[7] Cost Benefit Analysis Checklist, HSE,
This paper is available at http://www.hse.gov.uk/risk/theory/alarpcheck.htm

[8] NOPSEMA ALARP Guidance Note N-04300-GN0166 Rev 3 Dec 2011.
This paper is available at
http://www.nopsema.gov.au/assets/document/N-04300-GN0166-ALARP.pdf

[9] NOPSEMA Hazard Identification Guidance Note N-04300-GN0107 Rev 4 Dec 2011.
This paper is available at
http://www.nopsema.gov.au/assets/document/N-04300-GN0107-Hazard-Identification.pdf

Appendix B ICAF

In making an assessment of reasonable practicability, there is a need to set a pre-defined criteria on the Implied Cost of Averting a Fatality (ICAF), which is calculated as:

ICAF = Net cost of measure / Reduction in fatality risks.

For the purposes of this *ALARP Demonstration Guidance Document,* the CER is proposing that a Defined ICAF of at least **€2,400,000** shall be used.

This value is based on an existing determination made by the National Roads Authority (NRA) which is the only comparable figure which the CER found employed by another statutory agency in Ireland. The NRA has calculated accident costs and at resource costs (2009 prices and values) the cost per fatality was calculated at €2,060,099[18] which is €2,4000,000 in 2013 prices.

For example, this means that a risk reduction measure that saves a life over the lifetime of the risk reduction measure and for which the cost is not grossly disproportionate to €2,400,000 is reasonably practicable. However, it remains the duty of the Petroleum Undertaking to demonstrate that the cost of the risk reduction measure in question is grossly disproportionate to the safety benefit achieved.

By way of comparison with other jurisdictions, in the UK the HSE[19] set the value of a life at £1,336,800 in 2003, which is approximately €2.25M in 2013. (Assuming £1 = €1.25 and the value is increased by 3% each year for 10 years).

It is noted that the Central Expenditure Evaluation Unit (CEEU) within the Department of Public Expenditure and Reform (DPER) is in the process (in late 2012) of developing best practice in the evaluation and implementation of programme and project expenditure within the Irish public sector within a Public Spending Code[20]. Once complete, this Public Spending Code will specify parameter values needed for the quantification of costs and conducting CBAs and it may include a value equivalent to the ICAF. If and when the CEEU specify such a figure, the CER will review the recommended ICAF figure of **€2,400,000** in this guidance.

[18] See Reference [2]
[19] See Reference [3]
[20] See http://publicspendingcode.per.gov.ie/

Appendix C Gross Disproportion Factor

In a cost benefit analysis, a factor is used to show when the cost of an additional risk reduction measure is grossly disproportionate to the benefits that it brings. The sacrifice, seen as the cost of the measures necessary to avert the risk, is calculated as the costs of implementation in terms of money, effort or trouble, and this must be disproportionately greater than the calculated safety benefits of the risk reduction achieved before the measure can be disregarded. However, if gross disproportion can be demonstrated, then the risk reduction measure is classified as not reasonably practicable and there is no requirement for it to be implemented as part of an ALARP demonstration.

The UK HSE advise a gross disproportion factor of between 2 and 10, with the former applying to members of the public in a low risk situation and the latter to high risk situation[21].

A figure of **at least ten** for the Gross Disproportion Factor is advised. This is because if a quantitative risk assessment is being used for the decision on whether a risk reduction measure should be implemented, as opposed to a less sophisticated type of assessment, it is clear that the decision on whether to implement cannot be easily made and, given the inherent uncertainty in any risk assessment, a larger factor is more prudent.

---

[21] See http://www.hse.gov.uk/risk/theory/alarpcba.htm

Appendix D Justification of Risk Limits

D.1 Individual Risk

D.1.1 Risk Limits

Individual risk expresses the risk to a single person. The scale of an accident, in terms of the number of people impacted by an event, does not affect individual risk. The risk limits advised are shown in Table 3.

Individual	Upper Tolerability Limit	Lower Tolerability Limit
Worker	10^{-3}	10^{-6}
Public	10^{-4}	10^{-6}

Table 3: Individual risk limits for workers and the general public

D.1.2 Comparison with Other Risk Limits in Ireland

The HSA paper on COMAH land use planning in Ireland[22] uses a risk-based methodology. For new facilities it must be demonstrated that the risk of individual fatality is not greater than 5×10^{-6} per year to current non-residential neighbours or a risk of individual fatality is not greater than 10^{-6} per year to the nearest residential neighbours. Otherwise the risks are not broadly tolerable.

The HSA COMAH land use planning policy report, quotes an individual risk of fatality of 10^{-3} per year for workers within the offshore industry, or other high risk industries, as the maximum tolerable individual risk. The report states 10^{-4} per year as the maximum tolerable risk of fatality for people off-site (public) from all potential major accidents.

D.1.3 International Comparison

For land use planning criteria in the UK, the HSE propose a broadly acceptable individual risk level of one in a million (10^{-6}) per year. Similarly for land use planning in the Netherlands, safety distances have been defined in the regulations based on a 10^{-6} fatality per year individual risk criterion. Risk tolerability criteria, developed with public consultation in Western Australia, specified that a risk of 10^{-6} fatalities per year for residential areas was a risk so small as to be acceptable. An individual risk of one in a million (10^{-6}) per year is therefore seen as an acceptable level of everyday risk for the general public.

The HSE policy document *Reducing Risks Protecting People*[23] states a limit of 10^{-4} per year of fatality for people off-site (public) from all potential major accidents.

The, HSE Offshore Information Sheet No. 3/2006[24] and HSE policy document *Reducing*

[22] See Reference [4].
[23] See Reference [6].
[24] See Reference [5].

Risks Protecting People[25] quote an individual risk of fatality of 10^{-3} per year for workers within the offshore industry, or other high risk industries, as the maximum tolerable individual risk.

D.2 Societal Risk

D.2.1 Risk Limits

Major Accidents have the potential to affect large numbers of people. Societal risk expresses the cumulative risk to groups of people who might be affected by such events and are represented by FN curves. The slope of the FN curve represents the degree of risk aversion to multiple fatality events. The more negative the FN curve slope then the more risk aversion is being adopted. Figure 6 in Section 5 of this document and Figure 7 below shows the FN curve advised in this guidance.

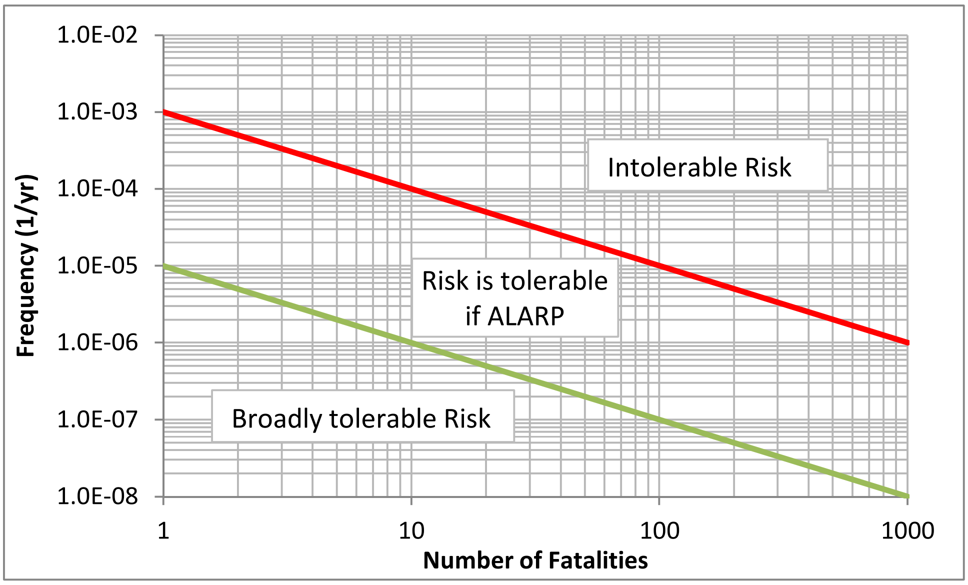

Figure 7: Options for the FN curve for the general public

D.2.2 Comparison with Other Risk Limits in Ireland

The HSA paper on COMAH Risk-based Land Use Planning in Ireland[26] gives figures for societal risk of an intolerable region (which would invoke a decision against planning approval) with an upper value of 1 in 5,000 years for 50 fatalities and a broadly tolerable region (which would invoke a decision for planning approval) of 1 in 100,000 years for 10 fatalities. The former figure lies in the intolerable region and the latter in the middle of the risk is tolerable of ALARP region.

D.2.3 International Comparison

The UK HSE document *Reducing Risks Protecting People*[27] set a FN curve with a slope of -1

[25] See Reference [6]
[26] See Reference [4]
[27] See Reference [6]

passing through 50 fatalities with a frequency of 2×10^{-4} for maximum tolerable societal risk. In the UK, this figure can include workers at a hazardous site, whereas the criteria in Ireland is for members of the public only. This allows Ireland to set a risk tolerability criteria of an FN curve with a slope of -1 passing through 50 fatalities with a frequency of 2×10^{-5}, which is lower than the UK figure.

Taking a comparison with events in the UK with at least ~50 fatalities for members of the public from all potentially hazardous events including mining, transportation, large-scale sporting events, the actual frequency of such events is approximately once every five years. Given the broad definition of such sites (that includes, for example, the multiplicity of sporting venues and mass transportation), the number of sites is likely to be between 1,000 and 10,000 meaning that the historical figure for 50 fatalities amongst the general public is between the UK figure (though this figure includes workers and so is not a direct comparison) and a factor of 10 lower. The lower figure is chosen for Ireland in order to aim for continual improvement. Note that major accidents in Ireland are less frequent than the UK due to the country's smaller size making it less easy to draw comparisons.

Appendix E Overview Diagram of Framework

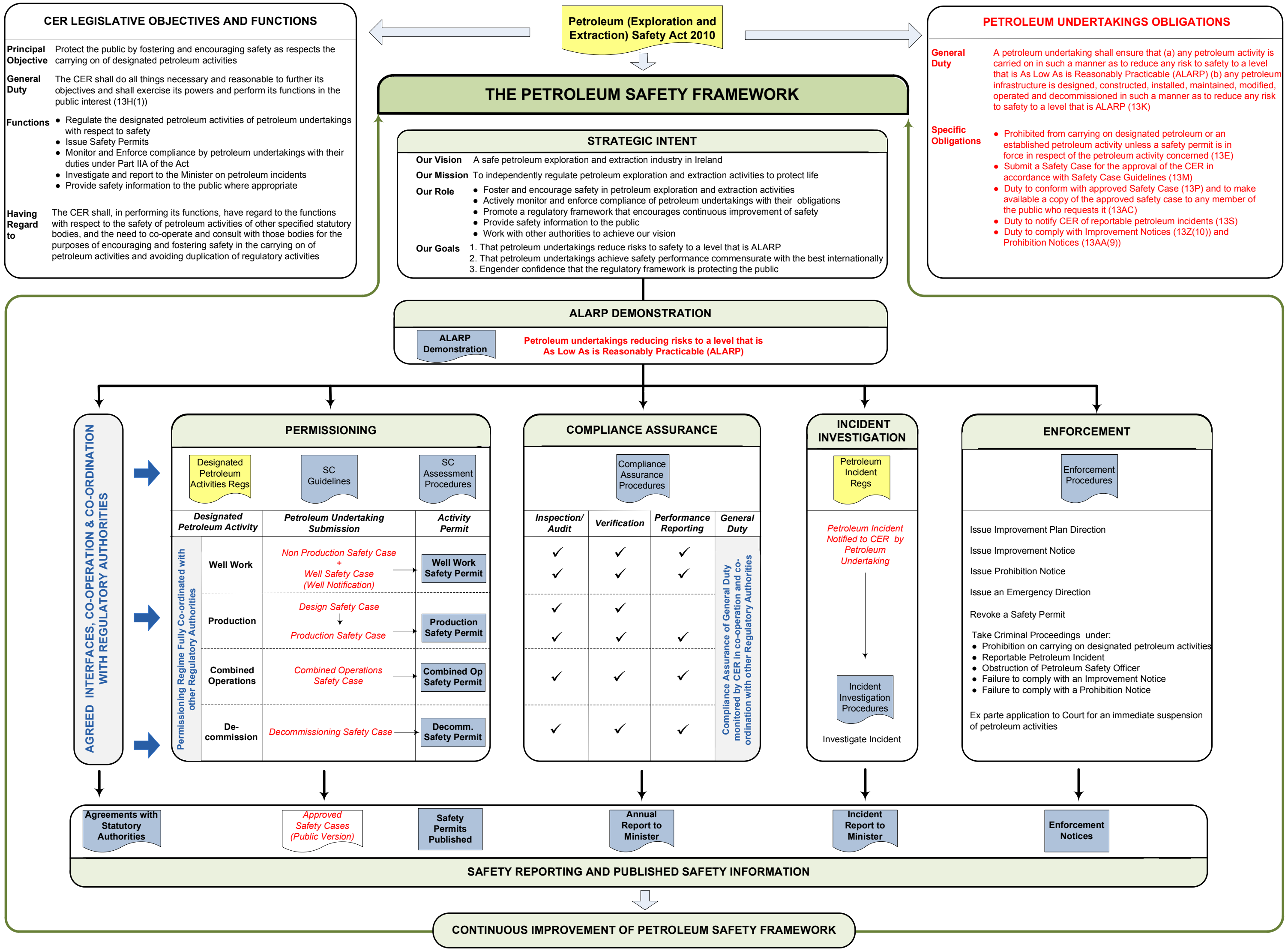

Figure 8: Overview Diagram of Framework