An Coimisiún um Rialáil Fóntais

Commission for Regulation of Utilities

ALARP Guidance

Part of the

Petroleum Safety Framework

and the

Gas Safety Framework

Decision / Information Paper

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VERSION CONTROL

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Public Interest Statement

The Petroleum Safety Framework and the Gas Safety Framework sit within the CRU Energy Safety Division. They are the frameworks under which the CRU regulates petroleum and gas undertakings against their duties under Irish legislation. Petroleum and gas undertakings include producers and explorers onshore and offshore in Ireland and undertakings that ship and supply gas onshore in Ireland respectively.

The Petroleum and Gas Safety Frameworks set out how the various undertakings are regulated, including how the CRU will ensure they are complying with their obligations and duties under legislation. While safety of petroleum and gas undertakings are regulated under different frameworks, both petroleum and specified gas undertakings are required to reduce all risks from their activities to a level that is as low as reasonably practicable, a term referred to as ALARP. The ALARP principle is a well-established principle and an ALARP assessment is a method used by undertakings to demonstrate that the Residual Risk from their activities is ALARP. The undertakings are required to document this ALARP assessment in a safety case they submit to the CRU. The CRU will carry out an assessment of this safety case and decide whether the activity can proceed.

The CRU previously published two versions of the ALARP Guidance Document in 2013. These were only applicable to the CRU Petroleum Safety Framework. Limited guidance for natural gas and certain specified LPG undertakings was provided for in the relevant GSF documentation. The ALARP Guidance Document has now been updated and this document is now the current version of the ALARP Guidance Document. Undertakings regulated under the Gas Safety Framework can now utilise this document to assist in developing their ALARP assessments in their safety cases which they submit to the CRU.

The primary audience for this paper is those industry participants who are required to submit safety cases to the CRU. However, the publication of this paper provides the public with an understanding of the safety requirements which the CRU place on industry in order to carry out their petroleum and gas activities in Ireland. The CRU intends that both frameworks will give confidence to the public that strong regulatory systems are in place for upstream and downstream petroleum and gas activities in Ireland.

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List of Abbreviations

Abbreviation	Meaning
ALARP	As Low As is Reasonably Practicable
CBA	Cost Benefit Analysis
CRU	Commission for Regulation of Utilities
FN	A measure of societal risk where F is the cumulative frequency of N or more fatalities
GDF	Gross Disproportion Factor
GSF	Gas Safety Framework
HSA	Health and Safety Authority
HSE	UK Health and Safety Executive
ICAF	Implied Cost of Averting a Fatality
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
MAH	Major Accident Hazard
NSAI	National Standards Authority of Ireland
PSF	Petroleum Safety Framework
QRA	Quantitative Risk Assessment
SSIV	(Pipeline) Sub-sea Isolation Valve

Glossary of Defined Terms

Term	Definition or Meaning
ALARP Assessment	The process used to determine whether a risk is ALARP. It incorporates various stages including comparison with Risk Tolerability Limits and consideration of all practicable risk reduction measures.
ALARP Guidance	This document, which describes processes that must be used to determine whether a safety risk is ALARP. The *ALARP Guidance* document, as amended from time to time, forms part of the Frameworks.
Decision Process	Process used to decide if a risk reduction measure is reasonably practicable. Guidance on the Decision Process forms a key part of this guidance.
Defined/Calculated Implied Cost of Averting a Fatality	The Defined ICAF is a pre-defined monetary value for use in a cost benefit analysis that can be compared to a Calculated ICAF for a risk reduction measure. If the Calculated ICAF is greater than a multiple (defined as the Gross Disproportion Factor) of the Defined ICAF, the cost of the risk reduction measure is said to be grossly disproportionate to the risk reduction it provides. The Defined ICAF may be published by the CRU from time to time, is indexed linked and is at least €3,100,000 in 2022 prices.
FN Curve	An FN Curve plots the cumulative frequency of N or more fatalities over the range of fatalities possible.
Framework(s)	Refers to the Petroleum Safety Framework and the Gas Safety Regulatory Framework.
Gas Safety Regulatory Framework	The Gas Safety Regulatory Framework (GSF) established under the Electricity Regulation Act 1999 as amended by *inter alia* section 12 of the *Energy (Miscellaneous Provisions) Act 2006* and extended under section 17, 18 and 19 of the *Energy (Miscellaneous Provisions) Act 2012* that comprises the collection of regulations, written regulatory documents and procedures which, taken together, describes the system the CRU uses to regulate the activities of natural gas undertakings and certain LPG undertakings with respect to safety.
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.
Hazard	Source of potential harm.

Term	Definition or Meaning
Implied Cost of Averting a Fatality	The ICAF is the cost of a risk reduction measure divided by the reduction in Potential Loss of Life that it provides over its lifetime.
Infrastructure	Petroleum infrastructure as defined in the *Petroleum (Exploration and Extraction) Safety Act 2010,* as amended by the Petroleum (Exploration and Extraction) Safety (Amendment) Act 2015 and any natural gas infrastructure and piped LPG distribution network as defined in the *Energy (Miscellaneous Provisions) Act 2012.*
Lower Tolerability Limit	The boundary between risks that are broadly tolerable and those that are tolerable if ALARP.
Major Accident	Has the same meaning as defined in the PSF and GSF, or in the Acts under which these Frameworks are established.
Major Accident Hazard	A hazard that if realised could result in a Major Accident.
Operator / Owner	Have the same meaning as defined in the PSF or in the Act under which the PSF is established.
Petroleum Safety Framework	The Petroleum Safety Framework (PSF) established under the Electricity Regulation Act 1999 as amended by *inter alia* section 13I of the Petroleum (Exploration and Extraction) Safety Act 2010, as amended by the Petroleum (Exploration and Extraction) Safety (Amendment) Act 2015, that comprises the collection of regulations, written regulatory documents and procedures which, taken together, describes the system the CRU uses to regulate the activities of petroleum undertakings with respect to safety.
Potential Loss of Life	The sum, across all hazardous events and scenarios being considered, of the average annual fatalities, where the average is calculated as the annual frequency of an event multiplied by the number of fatalities resulting from it.
Residual Risk	The risk that remains once a risk reduction measure has been implemented.
Risk	The likelihood of a given consequence.
Risk Assessment or Risk Analysis	The process used to assess and comprehend the risk from a hazard, or number of hazards. Risk analysis provides the basis for comparison of the risk with the Risk Tolerability Limits.
Risk Reduction Measure	A measure that reduces the risk from a hazard.
Risk Tolerability Limits	The CRU's Upper Tolerability Limit and/or Lower Tolerability Limit for individual risk, or societal risk, as the context requires.

Term	Definition or Meaning
Safety Case Guidelines	Has the same meaning as defined in the PSF and GSF, or in the Acts under which these Frameworks are established.
Undertaking	A petroleum undertaking, natural gas undertaking or certain LPG undertakings as defined in the PSF and GSF, or in the Acts under which these Frameworks are established.
Upper Tolerability Limit	The boundary between intolerable risks and risks that are tolerable if ALARP.

1 Introduction

1.1 Legal Context

The Electricity Regulation Act 1999, as amended inter alia by the Petroleum (Exploration and Extraction) Safety Act 2010 and the Petroleum (Exploration and Extraction) Safety (Amendment) Act 2015, gives the Commission for Regulation of Utilities (CRU) responsibility for the safety regulation of petroleum exploration and extraction activities in Ireland. This Act requires the CRU to "establish and implement a risk-based Petroleum Safety Framework". The Petroleum Safety Framework (PSF) is the overall system established by the CRU to regulate the safety of designated petroleum activities[1]. The PSF is a permitting regime. It is goal-setting and risk-based and requires that risks from petroleum activities are reduced to a level that is as low as reasonably practicable or ALARP.

Section 12 of the Energy (Miscellaneous Provisions) Act 2006 amends the Electricity Regulation Act 1999 to give the CRU responsibility to regulate the activities of natural gas undertakings with respect to safety and requires the CRU to discharge this responsibility through the implementation and ongoing operation of a Gas Safety Regulatory Framework (GSF). The licensed natural gas undertakings that are regulated under the GSF include liquefied natural gas (LNG), storage, transmission, distribution, and shipper and supplier undertakings.

Section 14 of the 2006 Act further amends the Electricity Regulation Act 1999 to provide for an extension of the CRU's gas safety powers to liquefied petroleum gas (LPG) although this was not enacted until the publication of the Energy (Miscellaneous Provisions) Act 2012. The CRU now has powers to regulate natural gas and certain specified LPG undertakings with respect to safety and this responsibility is also discharged through the GSF. Like the PSF, the GSF is risk-based and it implements the principle that all natural gas and LPG undertakings must ensure that the risks they create are reduced to a level that is ALARP.

1.2 This Document: ALARP Guidance

This *ALARP Guidance* document provides detailed guidance on the requirements of the CRU for an assessment under the PSF or GSF to demonstrate that a safety risk is ALARP. This assessment is termed an ALARP assessment. It is a requirement of the CRU that the ALARP assessment process set-out in this document, or a process that achieves the same objectives, is followed.

While this document describes the ALARP assessment process, the *Safety Case Requirements* within the PSF and the *Safety Case Guidelines* within the GSF describe how the ALARP assessment must be documented, where relevant, in a safety case.

Under the PSF and GSF (the Frameworks), the responsibility to carry out and document an ALARP assessment lies variously with Undertakings, Operators and/or Owners. This *ALARP Guidance*

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[1] Petroleum Safety (*Designation of Certain Classes of Petroleum Activity) Regulations* 2013

applies to all who have such responsibilities under the Frameworks or the Acts under which the Frameworks are established.

Consistent with the requirements for safety cases, this *ALARP Guidance* focusses on the assessment of safety risks from Major Accident Hazards (MAH), but also addresses safety risks from non-MAH.

In preparing this document, the CRU has drawn on guidance issued by statutory bodies regulating safety in the oil and gas industry in the UK and Australia and industry bodies in the UK. The CRU may amend this document from time to time to take account of changes in national or international practice.

This document is divided into 3 further sections:

- Reasonable Practicability in Irish Law (Section 2);
- ALARP Assessment (Section 3); and
- Risk Tolerability Limits (Section 4).

The appendices cover:

- Appendix A References
- Appendix B Use of Risk Assessment in ALARP Assessments
- Appendix C Defined ICAF
- Appendix D Gross Disproportion Factor
- Appendix E Justification of Risk Tolerability Limits

2 Reasonable Practicability in Irish Law

2.1 The Concept of Reasonable Practicability

The concept of what is 'reasonably practicable' was first considered by the Court of Appeal in the UK in the case of *Edwards v National Coal Board 1949*[2] where L.J. Asquith 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]* 2 I.R. 460. The Supreme Court, in dealing with the concept of what was 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 considered between the risk removed by a particular precaution and any risk created by the implementation of that measure.

The courts in Ireland have accepted the UK position that in applying the ALARP principle a risk reduction measure must be adopted unless the sacrifice involved in implementing that measure is grossly disproportionate to the risk reduction gained. The ALARP principle arises from the fact that boundless time, effort and money could be spent in the attempt to reduce a risk to zero, but that some limit must be placed on how far a duty holder must go to discharge their duty, otherwise economic activity would cease, and this limit is defined to be one of reasonable practicability. What is reasonably practicable in any given situation will be determined by the facts of the case.

2.2 Obligation to Ensure Risks are ALARP

The fundamental obligation under the Frameworks (i.e. the PSF and the GSF), is to reduce all risks to safety to a level that is ALARP. This obligation lies variously with Undertakings, Operators and/or Owners. It 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 and that the residual risk is ALARP. A key regulatory goal of the Frameworks is to ensure that this obligation is fulfilled.

The ALARP demonstration forms a central part of each safety case submitted under the PSF or the GSF.

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[2] Edwards v National Coal Board [1949] 1.K.B. 704

3 ALARP Assessment

3.1 Overview of the ALARP Principle

The fundamental principle of risk-based hazard management is that whilst risks cannot always be completely eliminated, it should be possible to reduce them to a level that is ALARP, so that they are tolerable to society because all reasonably practicable risk reduction measures have been implemented. The management of hazards, such that the risks to safety are ALARP, must be demonstrated, and in industries where there is a possibility of a Major Accident, the mechanism for such a demonstration is through a safety case.

The ALARP principle is illustrated in Figure 1. The triangle represents an increasing level of cumulative risk (all risks, or the total risk, that a person, or population are exposed to) from a low risk, represented by green at the base of the triangle, to a high risk, represented by red at the top of the triangle.

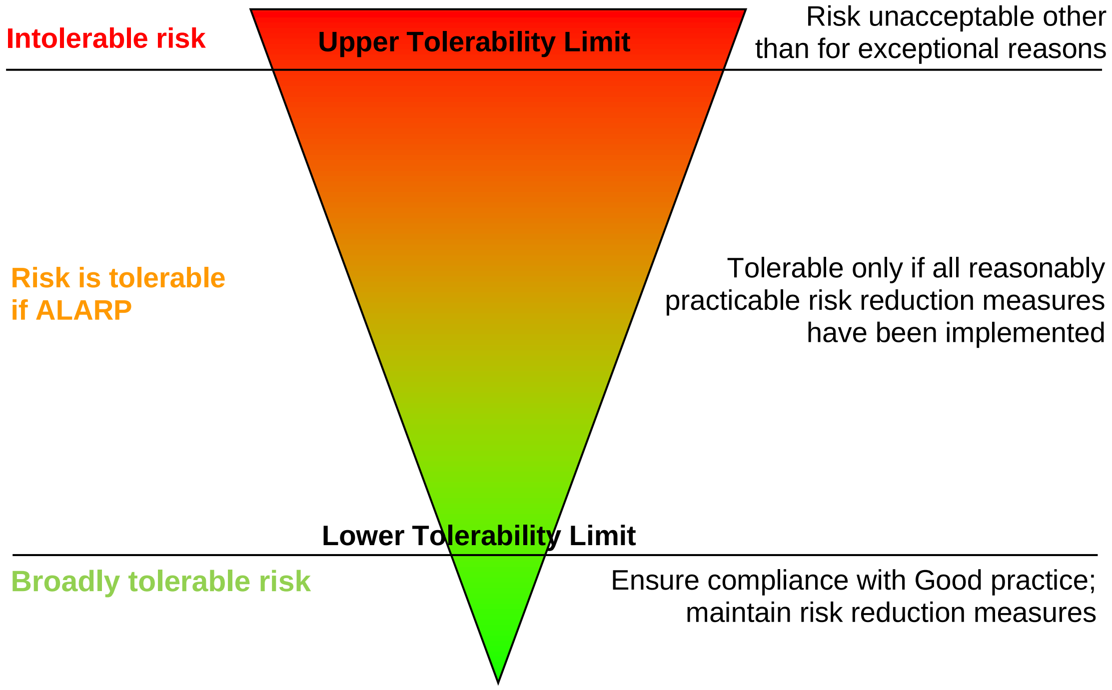

Figure 1: Schematic diagram illustrating the ALARP principle

Figure 1 shows the Upper Tolerability Limit, above which risks are intolerable and will only be permitted for exceptional reasons.

Below the Upper Tolerability Limit, the risk is only tolerable if it is ALARP. This means that all reasonably practicable risk reduction measures must have been identified and implemented. As introduced in Section 2, the term reasonably practicable indicates a narrower range than all physically possible risk reduction 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 the hazard, then it may not be required to implement the measure. Where the risk(s) in question are between the Upper Tolerability Limit and the Lower Tolerability Limit, a detailed ALARP assessment will be required. This must show that current Good Practice has been followed and that all reasonably practicable risk reduction measures have been implemented.

Figure 1 also shows the Lower Tolerability Limit below which the risks are broadly tolerable to society and comparable to everyday risks faced by the general public. If the cumulative risk is below the Lower Tolerability Limit, the ALARP assessment is likely to be straightforward and limited to ensuring compliance with Good Practice. Below the Lower Tolerability Limit, the principal risk management concern is the maintenance of existing risk reduction measures to avoid degradation.

Values for the Risk Tolerability Limits and further guidance on them are given in Section 4.

3.2 Risk Management Process

In carrying out an ALARP assessment, a risk management process (also termed hazard management process) must be followed that incorporates the ALARP principle. This section describes the CRU's expectations of such a process and it, or a process that achieves the same objectives, must be followed. Figure 2 shows a flowchart that encapsulates the CRU requirements.

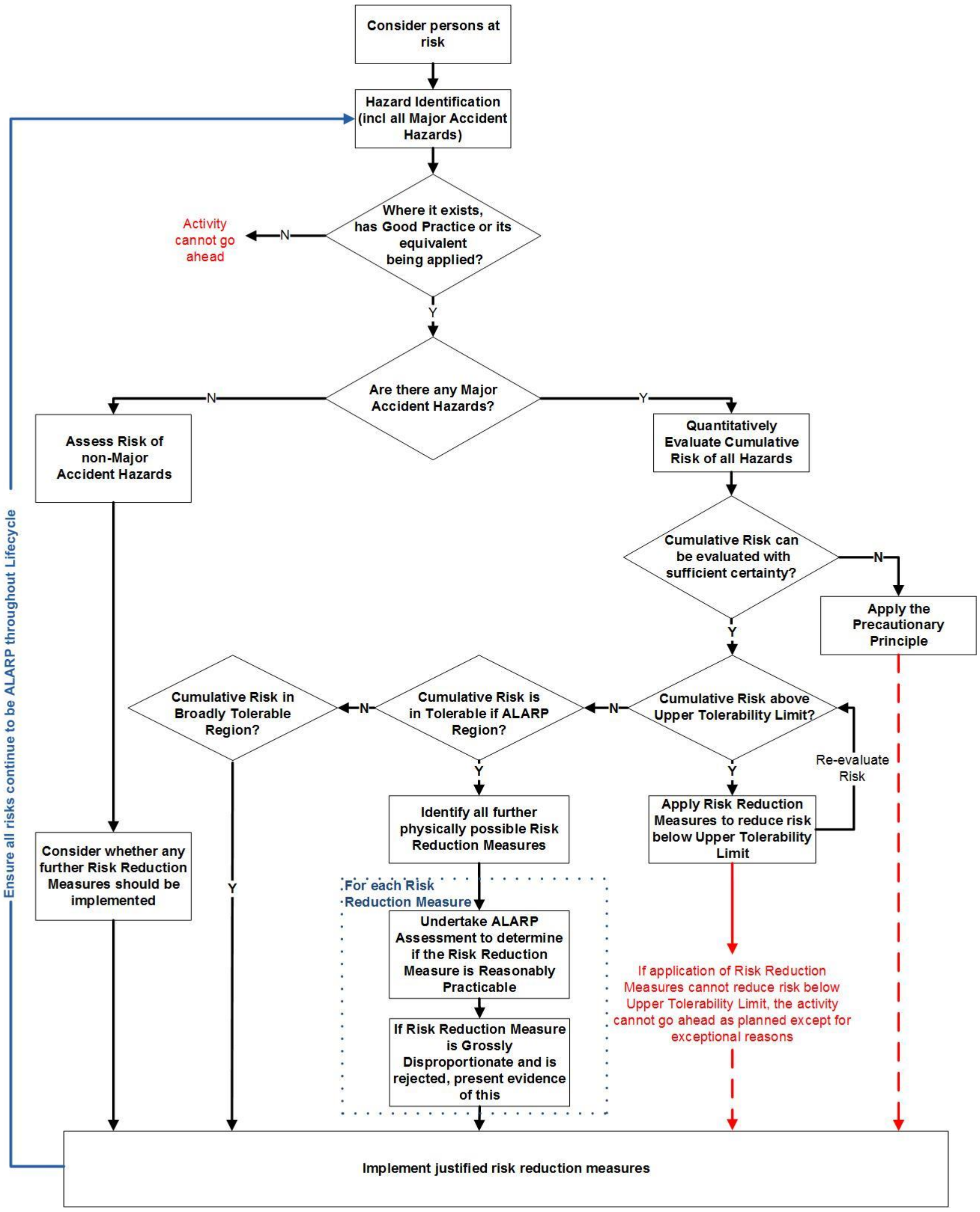

Figure 2: Hazard identification and risk management process incorporating the ALARP principle

The steps in the process in Figure 2 are:

1. A comprehensive identification of all hazards associated with the activity including specific identification of MAH (Section 3.3);

2. Where Good Practice exists, this or its equivalent must be implemented (Section 3.4);

3. If there are MAHs associated with the activity:
   a) A quantitative assessment of the cumulative safety risk associated with the activity must be carried out, considering both MAH and non-MAH but with specific assessment of the MAH(s):
      - In circumstances where the risk of an identified MAH cannot be assessed with sufficient certainty to be reliably compared with the Risk Tolerability Limits, recourse must be made to the precautionary principle (Section 3.6.6); and
      - If the risk can be assessed with sufficient certainty, follow step 3(b).

   b) Compare the cumulative risk from all hazards to the Upper and Lower Tolerability Limits (Section 3.5):
      - If the cumulative risk is above the Upper Tolerability Limit (i.e. is intolerable), the activity is not permitted except for exceptional reasons, which would need to be justified to and agreed with the CRU. Otherwise, if the activity is to proceed, risk reduction measures must be implemented regardless of whether they are reasonably practicable, until the risk is below the Upper Tolerability Limit. Once this has been achieved, the assessment carries on as for risks that are initially below the Upper Tolerability Limit (step 3(c)); and
         - If the cumulative risk is below the Lower Tolerability Limit, following on from step 2, demonstrate that relevant Good Practice has been identified and implemented and that arrangements are in place (including periodic review) to ensure ongoing compliance.

   c) If the cumulative risk is between the Upper and Lower Tolerability Limits, identify all physically possible risk reduction measures (Section 3.3.3):
      - Implement each risk reduction measure unless it is demonstrated and documented that it is not reasonably practicable to do so (Section 3.6); and
      - If the safety benefit of a risk reduction measure cannot be assessed with sufficient certainty to determine if it is reasonably practicable, recourse must be made to the precautionary principle (Section 3.6.6).

4. If there are no MAHs associated with the activity:
   a) A suitable and sufficient assessment of the risks associated with the activity must be carried out, which is likely to be qualitative or semi-quantitative and direct comparison with the Risk Tolerability Limits is not required. Then:
   b) Identify any further risk reduction measures that could be implemented; and
   c) Implement those risk reduction measures which are required by Good Practice, plus any others which are reasonably practicable (Section 3.7.3).

5. Ensure that all risks continue to be ALARP throughout the lifecycle of the infrastructure or activity (Section 3.9) by periodic review following this process.

3.3 Identification of Hazards and Risk Reduction Measures

3.3.1 Hazard Identification

The first stage in the risk management process is the comprehensive identification of hazards that could have a safety impact on people. The identified hazards are then fed into the ALARP assessment.

Hazard identification usually involves a brainstorming workshop carried out by a group of competent persons with knowledge of the particular site, project and/or activities to be undertaken. Most hazard identification techniques involve a team approach since an individual generally cannot have the depth of experience and expertise on all aspects of the site, activity and 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 hazard identification.

Hazards and their causes are diverse, and many different methods are available for hazard identification. The hazard identification methodology should be chosen to match the situation, activity and hazards that are being considered and information appropriate for the technique must be available. It may be a standard technique, following an established protocol, a modification of one, or a combination of several [1].

Hazard identification requires careful consideration of the ways in which an activity or equipment could fail and create a hazard, which may include:

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

When considering how the risk from a hazard may be realised, it is not sufficient to just consider the direct past experience of the persons carrying out the hazard identification, or the experience of the activity, or site being considered. Every effort must be made to think how failures might occur, to identify their causes, potential consequences and the risk reduction measures that are needed to remove or reduce the risk from these failures.

Hazard identification must be managed in a formal process with accurate recording of the scope and the outcome. Defining the scope of the hazard identification is important as it must be clear that it covers the totality of the activity being considered, otherwise the full range of 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.

3.3.2 Major Accident Hazard Identification

In the hazard identification process, all MAHs should be specifically identified. As illustrated in Figure 3, these hazards have a low frequency but high consequence and because of this and their typical complexity, they are more difficult to manage than simpler, high frequency low consequence occupational or 'day-to-day' non-MAHs. For this reason, MAH are a particular focus of the Frameworks and hence the ALARP assessment.

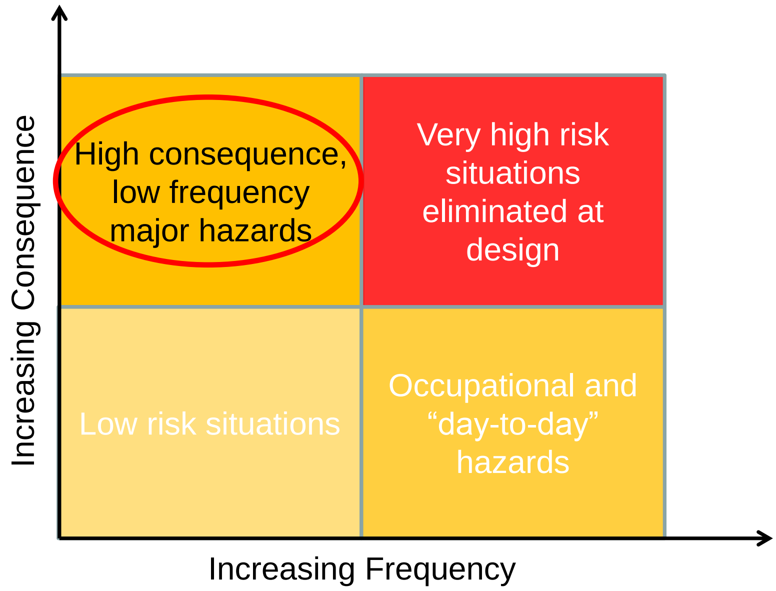

Figure 3: Illustration of the comparative frequency and consequence of major accident hazards

Hazard identification 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 the risk reduction measures needed to manage them will be detailed in suitable codes and standards (i.e. in Good Practice). 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 and the associated risks assessed.

3.3.3 Risk Reduction Measures

As part of the hazard identification process, risk reduction measures already implemented must be identified so that the residual risk can be assessed. Then, all physically possible additional risk reduction measures need to be identified, so that those deemed reasonably practicable can be implemented.

Identification of risk reduction measures is often best carried out at the same time as hazard identification, and the guidance in Section 3.3.1 for hazard identification also applies to risk reduction measure identification. Identified risk reduction measures should include those that are new, or are improvements to existing measures already implemented, e.g. in terms of equipment, improved maintenance, or operations. Risk reduction measures can either lower the possibility (frequency) of the hazard occurring or reduce its consequences, or both.

3.4 Good Practice

For all identified hazards and risk reduction measures, the adoption of current Good Practice, or its equivalent, is the first requirement in the hazard management process and so the first step of an ALARP assessment is to determine whether this requirement is met.

3.4.1 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 practices and measures are found in a variety of forms including:

- Guidance or codes of practice from national regulators;
- Standards from standards-making organisations (e.g. PSF *Safety Case Guidelines* include a list of technical standards from 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 accepted as an improvement.

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

- **Elimination**: Complete removal of a hazard;
- **Substitution**: Replacement of one part of an activity, process or design by another that is inherently less hazardous;
- **Prevention**: measures to reduce the frequency of a hazard;
- **Control**: measures to reduce the consequences of a hazard;
- **Mitigation**: measures to protect personnel from the consequences of a hazard; and
- **Emergency Response**: measures to protect personnel during the response to an emergency, including by removal of persons from the place of danger.

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

3.4.2 Applying Good Practice in ALARP Assessments

1. Good Practice in the management of hazards should be considered in the hierarchy set out in Section 3.4.1.

2. Good Practice evolves as knowledge and experience improves over time, and it is **current** Good Practice that forms the basis of an ALARP assessment. This affects the ALARP assessment in 3 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 is needed as to why the selected code is the most appropriate; and
   c) If a code or standard is updated such that an existing activity or infrastructure has potentially significant safety shortcomings compared to the new code, there is a need to assess whether it is reasonably practicable to make changes to meet the new code (see Section 3.7.7 for guidance on assessing reasonable practicability in this situation).

3. In assessing compliance with Good Practice, it is important to consider whether all aspects of an activity or design are covered by the Good Practice. It may be possible for each individual aspect to be covered by a prescriptive code that defines Good Practice, but no guidance be given for the sum of all of them. In this case, an ALARP assessment must be carried out for the totality of the activities. For example, Good Practice will guide the type of gas detectors in a particular circumstance, but further ALARP assessment is need to determine how many are required and where they should be located.

4. If Good Practice is defined for a particular hazard, activity or design, it should be implemented, or alternative measures should be implemented that are demonstrated to reduce the risks to at least the same degree. However, deviation from Good Practice will require more onerous justification.

5. Some codes and standards are risk-based and therefore do not give an absolute test of Good Practice (e.g. IEC 61511). However the methodology in such a code or standard should be followed as long as it complies with the remainder of this guidance.

6. Some Good Practice exceeds the standard that can be justified through cost-benefit analysis (e.g. the provision of an emergency response and rescue vessel for an offshore installation). Despite this, relevant Good Practice must be adopted if risks are to be reduced to ALARP (except as mentioned in 2(c) above regarding retrospective application of updated standards).

Where Good Practice exists, activities that do not meet it, or an equivalent, will <u>not</u> be accepted by the CRU.

3.5 Comparison of Risks Against Risk Tolerability Limits

3.5.1 Overview

If person(s) are exposed to a MAH, the cumulative risk to them must be calculated using quantitative risk assessment (QRA)[3]. The cumulative risk includes that from both MAH and non-MAH. Comparison of the cumulative risk with the Risk Tolerability Limits (defined in Section 4) then enables the appropriate assessment of whether the risk is ALARP as set out in Section 3.2, step 3. The detail required in the QRA must be such that the cumulative risk is calculated with sufficient certainty for this comparison.

Where person(s) are not exposed to MAH, direct comparison with the Risk Tolerability Limits is not required and the ALARP assessment should proceed as set out in Section 3.2, step 4.

3.5.2 Assessment Guidance

When considering the societal risk (see Section 4.3), which is applicable to the public only (i.e. not workers), the risk from all MAHs must be included in the assessment. This means that if two or more petroleum, natural gas or LPG activities can affect the same public population, the combined risk from these sources should be assessed and compared against the Risk Tolerability Limits.

When evaluating the risk to workers, the risks from all hazards must be included in the cumulative risk calculation, which means non-MAH as well as all MAHs. Less rigour is expected however, in the assessment of non-MAH risks compared to those from MAHs and the use of generic historical fatality data is usual for non-MAH if it is certain that the data is representative, or conservative.

The Risk Tolerability Limits are numerical expressions of the risk of fatality. Quantitative risk assessments must therefore calculate the risk of fatality in these terms.

Within the QRA, a conservative approach should be taken in the use of criteria to calculate when fatalities may occur.

For some activities that have the potential to realise MAHs, the risk may be well understood. For example, a pipeline built to a specific code for which the maximum risk (corresponding to construction to the limit of the code) is known. If this risk is known to be below the Upper Tolerability Limit, the calculation does not need to be repeated to show this for a particular pipeline, as long as it meets <u>all</u> aspects of the relevant code. Compliance with such a pipeline code is also Good Practice and if the code considers all practicable risk reduction measures, this will also demonstrate that risks are ALARP.

If the risk of the activity cannot be assessed with sufficient certainty to be reliably compared with the Risk Tolerability Limits, recourse should be made to the precautionary principle (see Section 3.6.6).

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[3] Within the PSF, further guidance is given in the *Safety Case Requirements*.

3.6 Determining what is Reasonably Practicable

3.6.1 Introduction

The following sections provide guidance on how to assess and demonstrate whether it is reasonably practicable to implement a risk reduction measure. The technique required for this assessment will vary according to the hazard, risk and risk reduction measure being considered. It is always the responsibility of the Undertaking, Operator and/or Owner, as applicable, to determine the correct technique to use.

A Decision Process is set-out in the remainder of Section 3.6 to enable the appropriate technique to be selected and justified, so that business, technical and other factors can be considered in fit-for-purpose ALARP assessments. The approach is adapted from that published by Offshore Energies UK (OEUK) [7].

3.6.2 Uncertainty

Within the risk management process, and key to this Decision Process, is a requirement that any assessment of reasonable practicability must be made with sufficient certainty. This is particularly relevant where a clearly safer option is not chosen, or there is sufficient uncertainty in the analysis to allow for the possibility that the selected option does not meet the Risk Tolerability Limits. In establishing that risks are tolerable, the margin between assessed risk levels and tolerability limits must be shown to significantly exceed any uncertainty in the risk assessment.

The more uncertainty (or complexity) associated with a decision, the more likely it is that more complex decision techniques will need to be deployed to minimise the uncertainty.

In determining the risk, the impact of realistic changes to inputs to the assessment and the assessment techniques themselves must be determined, if there is a possibility that they would change the result of the assessment. This does not mean that all parameters in the assessment need to be varied as some may have only a small effect on the final risk figure. Additionally, if there are potentially severe consequences, the risk assessment should be conservative, making it unlikely that uncertainties in the parameters result in a less-safe outcome being chosen.

3.6.3 Decision Context

The first step in the Decision Process is to determine the decision context, i.e. the combination of circumstances, knowledge and events within which the decision is to be made. Many factors and constraints will be important in determining the decision context. Those considered key are:

- The novelty and type of the proposed operations, technology, approach or methods; and
- The perceived risks and opportunities associated with the decision (i.e. the magnitude and likelihood of potential safety, environmental, economic, business or other outcomes, whether beneficial or adverse), and the degree of certainty with which these can be assessed.

Guidance is given below on how the above factors may affect the decision context.

Once the decision context has been determined, the Decision Process (Section 3.6.4) should be used to guide the selection of methods, or combinations of methods, likely to provide the most appropriate basis for assessing reasonable practicability.

3.6.3.1 Type of Activity

The type of activity to be undertaken, and the novelty of the operations, technology, approach and methods involved, will affect the decision context. The risk associated with common, well-understood situations is more likely to be controlled by the application of Good Practice, while less common situations will need risk assessment. For novel operations or technology the approach is more likely to adopt the precautionary principle as described in Section 3.6.6.

3.6.3.2 Risk and Uncertainty

It is fundamental that decisions regarding reasonable practicability must be made with sufficient certainty. Hence, factors that affect the certainty of the risk assessment process and results (e.g. novel technology) will also affect the decision context. Decisions made by reference only to Good Practice require a high degree of certainty as to the risks and their management. Increasing uncertainty implies a need to consider other assessment techniques.

3.6.3.3 Stakeholder Interest

Under the Frameworks, Undertakings, Operators and/or Owners, as appropriate are responsible for ensuring and demonstrating that safety risks have been reduced to ALARP.

ALARP assessments may however also be of interest to other stakeholders and Undertakings, Operators and/or Owners may wish to take account of stakeholder views. While this is **not** a regulatory requirement, the Decision Process does provide a means to do this. It is important to recognise however, that stakeholder interest will always move the decision context such that the decision is made by a process that is either more rigorous, or more conservative, i.e. towards a higher level of safety risk management, in excess of regulatory requirements.

3.6.4 The Decision Process Diagram

For different decision contexts, the Decision Process diagram (Figure 4) suggests the techniques that allow a reasonable practicability decision to be made with sufficient certainty.

In Figure 4, three different decision contexts (A, B and C) are shown for simplicity of presentation and a series of guide phrases, based on the factors above, aid in assigning the context type to a given decision. However, in reality, there is a continuum of context ranging from the most mundane decision to the most complex.

- For a **type A decision**, where the risk is relatively well understood, in general the decision will be determined by the application of recognised Good Practice. In cases where Good Practice may not be sufficiently well-defined, an engineering and/or risk assessment may be required to guide the decision.

- For a **type B decision**, involving greater uncertainty or complexity, the decision will not be made entirely by established Good Practice. Thus, while any applicable Good Practice will have to be met, there will also be a need for an engineering and/or risk assessment in order to support the decision and ensure that the risk is ALARP.
- A **type C decision** will typically involve sufficient complexity and/or uncertainty to require the precautionary principle to be adopted. In this case, relevant Good Practice will still have to be met and detailed engineering and/or risk assessment will still be used to support the decision.

The chevrons in Figure 4 indicate the technique(s) likely to be needed to make a decision. Whatever the context, Good Practice must be met and the risk must not to be intolerable. For a type A decision context, this may be sufficient to make the decision. Moving towards a type B decision context means that an engineering and/or risk assessment is likely to be needed to make the decision. For type A/B, B and B/C decision contexts, the arrow strength diminishes towards the base of the arrow to show the reduced relevance of that technique for such a decision. Towards and in the type C decision context, the precautionary principle is likely to be adopted to make the decision and, for this, an engineering and/or risk assessment will be needed to inform this approach. The colour is graded for the decision contexts to indicate that A, B and C are representative of a continuum of context.

3.6.5 Decision Methods

Once the decision context has been determined, the assessment techniques on which the reasonable practicability decision is likely to be based are illustrated in the Decision Process diagram. The following sections describe each of these techniques.

3.6.5.1 Good Practice

Where Good Practice exists, or a measure that gives an equal or better outcome, it must be followed. Therefore if a number of risk reduction options are being considered only those that meet or exceed relevant Good Practice should be taken forward. Section 3.4 defines Good Practice and provides guidance on application.

3.6.5.2 Engineering and Risk Assessment

Where Good Practice is not well-defined or where the particular circumstances of the decision are not fully within its scope, a more detailed engineering and/or risk assessment is required that takes account of the specific circumstances. Such an assessment may involve the use of a range of techniques and will require an understanding and application of sound engineering and scientific principles and methods.

Engineering assessment techniques that may be used include (but are not limited to):

- Engineering analysis (e.g. structural, fatigue, mooring, process simulation); and
- Consequence modelling (e.g. fire, explosion, ship collision, dropped object).

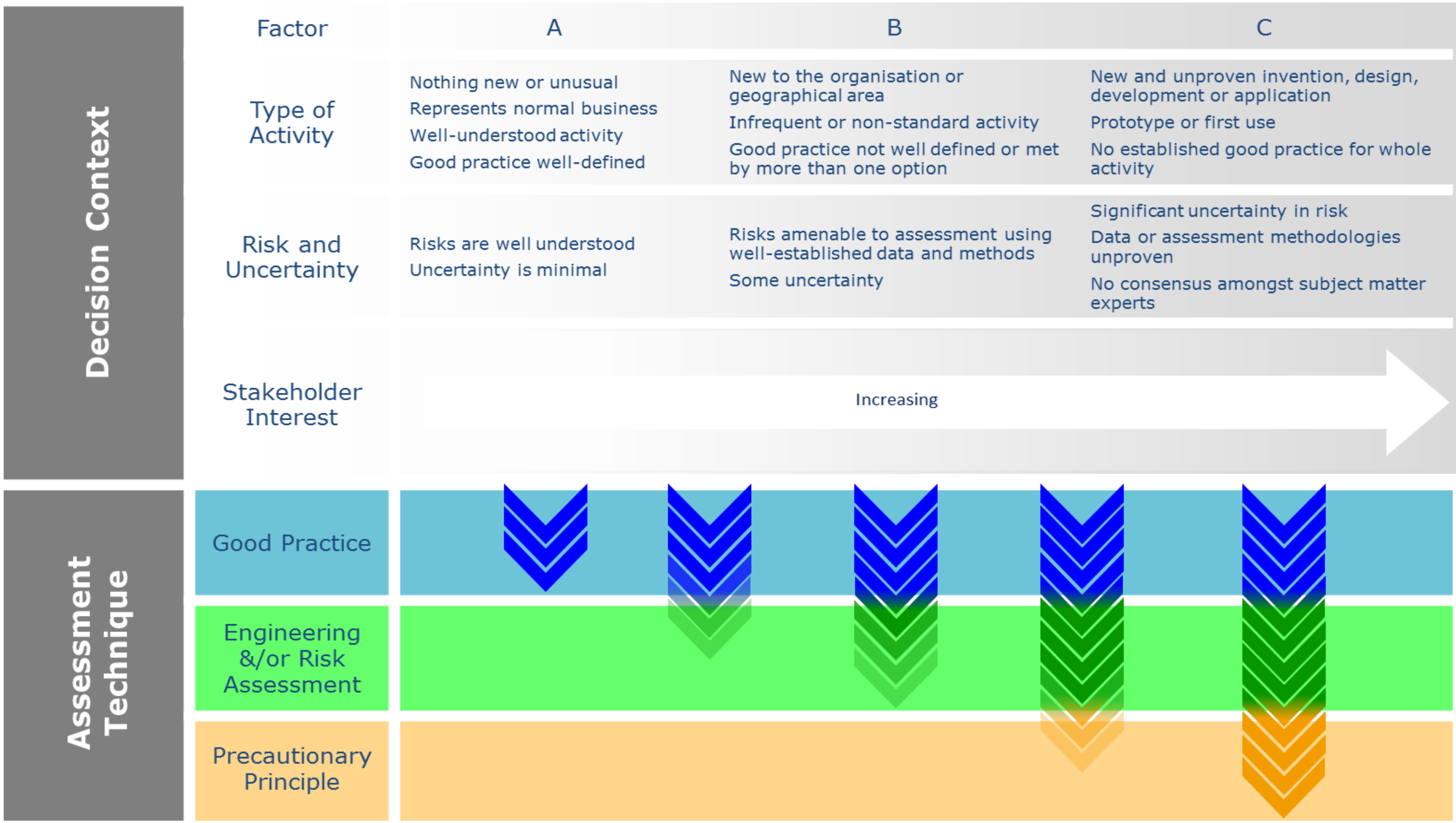

Figure 4: Techniques to determine reasonable practicability: Decision Process

If a decision can be made based on engineering assessment alone, there may be no need to reference the frequency of an event. For example, if a facility can be designed to withstand the maximum possible explosion overpressure, there is no need to determine the frequency with which this might occur. This is the preferred approach since it eliminates any reliance on the (low) likelihood of a hazard being realised.

Should it not be possible to eliminate the hazard, a risk assessment needs to be carried out to ensure that the remaining risk is ALARP. Risk assessment techniques can be described as qualitative, semi-quantitative and quantitative and this represents an increasing order of complexity and applicability to complex or uncertain issues. Appendix B provides guidance on the use of risk assessment in ALARP assessments, including the main factors which affect the level of sophistication of risk assessment that should be used. Within these risk assessments, techniques such as fault tree analysis, structural reliability methods and cost benefit analysis may be used.

A key issue in the selection of the risk assessment technique for an ALARP assessment is that it should be as simple as possible while able, with confidence, to differentiate between the risk with and without the risk reduction measures being considered, in place. Thus, for example, a risk matrix is a good tool for making decisions in relation to workplace risks, but is an inappropriate tool to justify a decision not to install a pipeline subsea isolation valve (SSIV). Conversely, a quantified risk assessment would not be beneficial for most workplace risks, as it would not be possible to find sufficiently accurate data to show the difference between risk reduction options, but it could be used to show the risk reduction gained from an SSIV.

Once a risk assessment has been undertaken, reasonable practicability may be shown by demonstrating that the residual risk is negligible, or a cost benefit analysis (CBA) carried out to show the balance between the risk benefit and the cost. Appendix B provides further guidance on CBA, including the concepts of Implied Cost of Averting a Fatality (ICAF) and the Gross Disproportion Factor (GDF).

Care must be taken when evaluating risk in a qualitative or semi-quantitative way and using the analysis to show that the residual risk is ALARP as these techniques usually do not give a direct measurement of risk to which the costs of a risk reduction measure can be compared.

It is important to note that the reasonable practicability decision is unlikely to be based on just one of these engineering or risk assessment techniques. Any assessment will need to take account of relevant Good Practice and potentially a combination of deterministic engineering analysis and risk assessment will be required. To provide a simple example for an area in a facility:

- Explosion analysis provides the worst case explosion overpressures.
- Engineering analysis indicates that design to these pressures would be impracticable.
- A risk assessment is then conducted to determine the design that provides protection that would reduce risks to a level that is ALARP.

In conducting a risk assessment, information may be drawn from a range of sources, including engineering analysis, generic industry data and Operator specific data. In all aspects, the process must be used in such a way that the decision can be made with sufficient confidence that the risks are reduced to a level that is ALARP.

In any assessment where more than one technique is used, if different techniques give different results, the results should not be combined by assigning weightings to results in order to arrive at a final decision. If different outcomes arise from different techniques, this indicates that the assumptions and data used in the assessments should be re-examined, or the use of the techniques themselves questioned. In general, the more sophisticated (quantitative) techniques give more certain results. Expert knowledge of the different assessment techniques is therefore required (see Appendix B) and if significant uncertainties remain, then the precautionary principle needs to be invoked.

3.6.6 Precautionary Principle

If the assessment, taking account of all available engineering and scientific evidence, is insufficient, inconclusive or uncertain, then the precautionary principle should be adopted in the hazard management process. This means that uncertain analysis is replaced by conservative assumptions which will increase the likelihood of a risk reduction measure being implemented. The degree to which this principle is adopted should be commensurate with the level of uncertainty in the assessment and the level of danger (hazard consequences) believed to be possible.

Under the precautionary principle, the hazards that are assessed should at least include the worst-case outcome that can be realised, but should not include hypothetical hazards where there is no evidence that they may occur. While the approach adopted is expected to be proportionate and consistent, under the precautionary principle, safety is expected to take precedence over economic considerations, meaning that a safety measure is more likely to be implemented. In this decision context, the decision could have significant economic consequences to an organisation in conjunction with the safety implications.

Adoption of the precautionary principle may result in the implementation of risk reduction measures for which the cost may appear to be grossly disproportionate to the safety benefit gained. However, in these circumstances, the uncertainty associated with the risk assessment means that the risk associated with non-implementation cannot be shown to be ALARP with sufficient certainty.

3.7 General Issues Relevant to Assessing Reasonable Practicability

3.7.1 Ranking of Risk Reduction Measures

A number of risk reduction measures that are being considered for implementation can be ranked at the start of an ALARP assessment so that, combined with costing information, the most effective risk reduction measures can be identified, or further analysed.

This ranking can use any of the techniques mentioned above, or other techniques as appropriate, as long as the process used to define a ranking is sufficiently robust that any decisions that are dependent on the ranking achieve sufficient certainty. The technique used must also allow any 'cut-off point' below which measures are not implemented to be well enough defined that there is a robust justification for all measures not implemented.

Where suitable data are available, the ranking of risk reduction options can be done through cost benefit analysis, based on quantified risk assessment (see Appendix B). Less sophisticated techniques can only be used if the differences in cost or risk are so large as to make the comparison certain.

3.7.2 Option Dependence

There can be some dependence between risk reduction options. For example, two options may be available, one relatively simple and low cost, the other more complex and higher cost, but giving greater risk reduction than the first. Taken on its own, the second option would be considered reasonably practicable; however, after implementation of the first option, it might not (i.e. the additional quantum of risk reduction might not be required for the risk to be ALARP). In these circumstances, other factors may form part of the decision process, for example the level of certainty associated with each risk reduction measure and their position in the risk reduction hierarchy described in Section 3.4.1.

3.7.3 Non-Major Accident Hazards

Where persons are only exposed to non-MAHs, meeting current Good Practice will generally achieve the reduction of risk to a level that is ALARP. In this case, vigilance is still needed in considering whether Good Practice is improving and relevant, or whether there are any additional hazards present that must be considered. This means that hazard identification and risk management is still needed and further risk reduction measures should still be identified and considered. Account can be taken of the level of risk identified, which means that measures that are of low cost and provide a clear risk reduction should be implemented.

It is unlikely that the more complex assessment techniques outlined in Section 3.6 will be required in an ALARP assessment for non-MAH. It is likely that a simple technique such as engineering judgement, qualitative risk assessment or (at most) a simplified, but conservative, quantitative analysis will be sufficient.

3.7.4 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 possible 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 credible and most likely events need to be modelled. In modelling different outcomes, it must be ensured that the total frequency of the hazardous event is accounted for.

Alternatively, just the worst-case credible outcome could be modelled assuming that every time the hazard 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 be implemented.

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

3.7.5 Cost of the Risk Reduction Measure

The cost of the measure, against which the safety benefit is being compared, should be restricted to those costs that are solely required for the measure. Realistic costs should be used so that, for example, the measure is not over engineered to derive a large cost, distorting the comparison to conclude that it would be grossly disproportionate to implement.

If the cost of implementing a risk reduction measure is primarily lost or deferred production or transportation, the ALARP assessment should be undertaken for the two cases where this cost is and is not accounted for. If the decision as to whether to implement a risk reduction measure is dependent on this additional cost (i.e. the measure would be installed without considering this cost), a robust argument as to why the measure could not be installed while losing less production or transportation (e.g. during an installation or pipeline 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 an 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 safety benefit, is implemented. An argument of grossly disproportionate correction costs cannot be used to justify an incorrect design.

3.7.6 Remaining Lifetime

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

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

3.7.7 Improvements in Good Practice

Over the life of an activity or infrastructure, improvements in Good Practice may occur which, if implemented, might significantly reduce safety risks (i.e. the infrastructure, or activity has potentially significant safety-related shortcomings compared to the new standard). It is recognised however, that the cost of modifying an existing activity or design to retrospectively address these deficiencies and comply with the new standard may be grossly disproportionate to the benefit gained and so a reasonable practicability assessment is necessary. This assessment will require an appropriate engineering and/or risk assessment, likely to include a cost benefit analysis. In this assessment it is appropriate to consider the remaining life of the infrastructure, although note should be taken of Section 3.7.6 if the remaining life is to be used as the reason for not implementing improvements.

3.7.8 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 assessment.

This does not prevent a suitably justified decision not to re-instate a risk reduction measure if either:

- The original reason for installing it changes due to, for example, elimination of a hazard; or
- The additional risks to those carrying out the re-instatement work exceed the risk benefit gained by restoring the measure to be fully functional (see Section 3.7.10 on risk transfer).

3.7.9 Representing the Real Risk

All risk assessment methodologies rely on input data. Whilst the use of generic data may be appropriate in the design stage or as a starting point for operating assets, it is important that the reality of the condition of any operating asset is taken into account. This is particularly important with ageing assets with known integrity issues, or where adequate inspection data is not available. The use of generic data in these circumstances is unlikely to give a true representation or measure of the risk and either asset specific information should be used, or the uncertainty recognised. Similarly, to ensure that the risk assessment models the real situation rather than an idealised situation, it must encompass engineering and operational understanding of the hazards being modelled.

3.7.10 Risk Transfer

In assessing different options, care should be taken to ensure that *all* of the risks to people are taken into account. A narrow view of the people affected can result in an option being selected that appears to give the best solution, but actually transfers risks to another group not considered within the assessment. For example, the retrospective installation of an SSIV on a stabilised crude oil line might reduce risks to personnel on the platform but will introduce risk to the divers installing it.

3.8 Documentation

The *Safety Case Requirements* within the PSF and the *Safety Case Guidelines* within the GSF describe how the ALARP assessment must be documented in a safety case.

A key part of the documentation of an ALARP demonstration is that it must describe those measures that have not been implemented and the reasons for this. This is especially important where circumstances or hazards change, as previously discarded measures might need to be implemented to maintain the risk ALARP. Also, in many cases a risk reduction measure may simply be provision of ‘more’ of a particular safety measure (e.g. more passive fire protection) and in this case the reason why it is not reasonably practicable to provide ‘more’ of the safety measure needs to be included in the ALARP demonstration.

3.9 Risk Reduction Measure Implementation and the Lifecycle

All risk reduction measures that have been assessed as being required to reduce risks to ALARP should be implemented.

All activities must be carried on in a manner that reduces all risks to safety to ALARP including that any infrastructure is designed, constructed, installed, maintained, modified, operated and decommissioned in a manner that reduces all risks to safety to ALARP. This requirement reinforces the need to consider the ALARP principle at all stages of the lifecycle of the 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, design decisions can fundamentally influence the risks. The concept and early design stages offer an opportunity to eliminate hazards and to make the design inherently safer. It is therefore important that the requirement for the risk to be ALARP is considered at the concept stage and throughout design and operations.

Figure 5 illustrates the impact that different risk reduction approaches can have at different stages of the lifecycle. The diagram shows the risk management hierarchy, overlaid with areas representing the concept, design and operational phases of the lifecycle. The overlays provide a qualitative illustration of the impact each risk reduction approach can have on the overall risk in the respective lifecycle phase.

The Concept phase overlay shows that elimination, substitution and prevention are the most important risk reduction measures in this phase and that they apply more to this phase of the lifecycle than any other. Eliminating hazards and ensuring inherent safety principles are applied is vital during the concept and design phases. During the operational phase, the emphasis on further risk reduction measures is towards control, mitigation and emergency response measures, as the fundamentals of the design cannot usually be changed meaning that hazards cannot usually be eliminated.

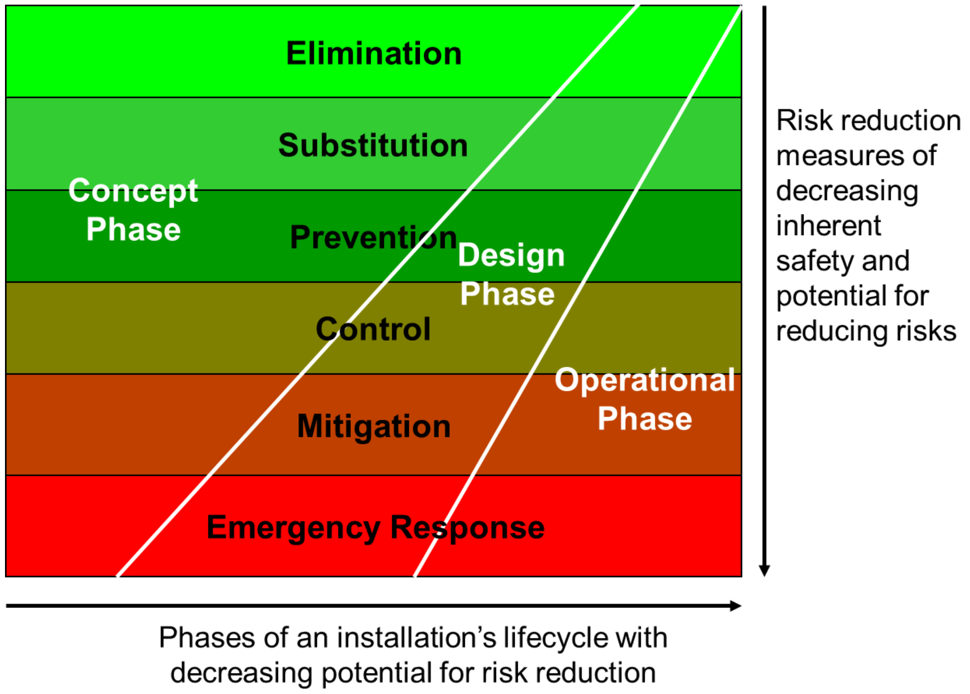

Figure 5: Risk reduction measures at different stages of the lifecycle.

As an activity progresses there is no guarantee that the risks will remain ALARP due to a number of factors including:

- Changes to the definition of Good Practice;
- Changes to an activity that may make it more hazardous;
- Changes in technology that allow for improved risk assessment or risk reduction measures;
- Learning from mistakes or incidents; and
- Learning from other operations.

Reducing risks to ALARP must be considered and re-considered throughout the lifecycle from early in the design phase through to the operational phase and beyond to decommissioning. It is incumbent on the Undertakings, Operators and/or Owners to continually review whether all the risks to safety remain ALARP.

3.10 Competency

The persons involved in the hazard management process, including the ALARP assessment must have competency, as a group, in:

- The operation or design of the infrastructure and activity being considered, particularly in relation to the associated hazards;
- The potential risk reduction measures; and
- The techniques of hazard identification, risk and ALARP assessment.

The hazard identification, risk assessment and ALARP assessments should, where appropriate, be undertaken as a team activity (e.g. hazard identification and the identification of risk reduction measures).

4 Risk Tolerability Limits

4.1 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, excluding workers).

The Risk Tolerability Limits are consistent with current practices in Ireland and internationally. While the limits provide guidance, all Undertakings, Operators and/or Owners are expected to abide by them. An explanation of why these figures are advised is given in Appendix E.

4.2 Individual Risk

Individual risk is the risk to a single person. In order for any 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.

	Upper Tolerability Limit (Fatalities per year)	Lower Tolerability Limit (Fatalities per year)
Worker	10^{-3}	10^{-6}
Public	10^{-4}	10^{-6}

Table 1: Individual Risk Tolerability Limits for workers and the general public

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

When considering the individual risk for members of the general public in normally occupied buildings nearby to an onshore site that is carrying on petroleum, natural gas or LPG activities or a pipeline, the calculations should take the likelihood of spending time inside the building compared to time spent outside as the ratio 9:1 (also termed the occupancy level).

In addition, individual risk calculations for persons affected by an Undertaking's activities should include any MAH risk presented to those persons by other Undertakings, as the Risk Tolerability Limits apply to the cumulative risk, not just the risk from the hazard or site being considered.

4.3 Societal Risk

Major Accident Hazards 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 limit the 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 the cumulative frequency (likelihood) of all events with N or more fatalities. FN Curves are typically plotted on a log-log scale as the frequency and number of fatalities range over several orders of magnitude.

The FN Curves that define the Risk Tolerability Limits are shown in Figure 6 with defining points given in Table 2, where the risk limit terms have the same interpretation as in Figure 1. The (red) FN Curve that defines the Upper Tolerability Limit has a slope of -1 and a frequency of 2×10^{-5} for 50 fatalities or more. The (green) FN Curve that defines the Lower Tolerability Limit is two orders of magnitude below the Upper Tolerability Limit.

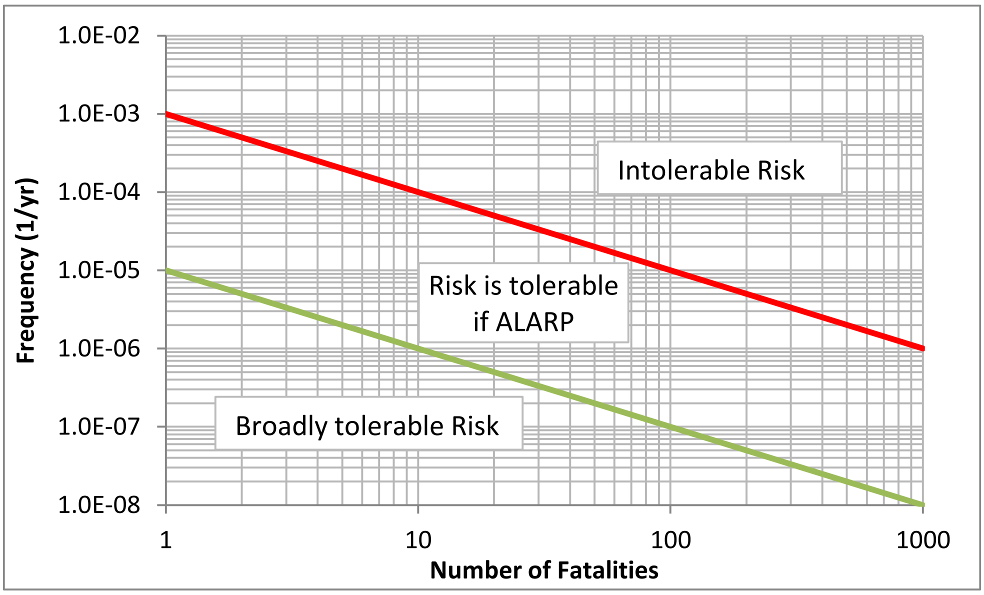

Figure 6: FN Curve showing the Risk Tolerability Limits for the public (excluding workers)

Fatalities (≥)	Upper Tolerability Limit (per year)	Lower Tolerability Limit (per year)
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 for members of the public (excluding workers)

For a pipeline, these figures apply to 1.6km of pipeline.

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

Appendix A. References

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Appendix B. Use of Risk Assessment in ALARP Assessments

B.1 Qualitative Risk Analysis

B.1.1 The Technique

Qualitative risk analysis is a method of assessing a risk without assigning any absolute values to the consequence, frequency, or risk. Consequence and frequency are typically assigned into a small number of bands described as, for example, very low, low, medium, high and very high. The risk is then expressed in similar terms. Qualitative risk assessments are typically done using a risk matrix.

B.1.2 Assessing Risk Reduction Measures

The accuracy of the technique is limited, and it should typically not be used to make decisions that are key to an ALARP assessment for MAH.

The technique is most suitable for determination of whether the risk from an operational task is ALARP, where the risk is more likely to arise from non-MAH. However, even in this case, the qualitative nature of the technique and coarseness of assessment means that it can only be used to assess well-understood hazards with well-understood risk reduction measures.

B.2 Semi-quantitative Risk Analysis

B.2.1 The Technique

In semi-quantitative risk analysis, numerical bandings of consequence and frequency are defined, which are combined together to give a risk banding by using a risk matrix, or a technique such as a layers of protection analysis. It provides a more sophisticated basis for assessing risk reduction measures than qualitative risk analysis, but is less accurate than quantitative risk assessment.

For semi-quantitative risk analysis to be used as part of an ALARP assessment the numerical bands that are used must be well-defined. Possible ways to quantify the bands for the frequency side of the risk assessment include:

- The consequence occurs every N years, where N varies between the bands, typically by an order of magnitude;
- The consequence occurs N times in the lifetime of an installation or pipeline; or
- The consequence occurs N times each year in the worldwide oil and gas industry.

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.

Whatever frequency and consequence bandings are chosen they must be as unambiguous as possible, to minimise the potential for inconsistent interpretation.

To be used successfully, there must be enough frequency and consequence bands to enable an ALARP assessment for the full range of scenarios intended to be covered by the risk assessment. The frequency of a MAH should be many orders of magnitude less than the frequency of a lost time injury and if both types of hazard are to be covered by the same matrix, multiple frequency bandings will be required.

In assessing risks using this technique, the potential for a number of different outcomes 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 carried out, it may not be obvious which is the highest risk outcome. In this case, a number of outcomes must be assessed in order to find the highest risk.

The assessment must however, avoid the potential for 'salami slicing' of the risk picture, whereby too many outcomes are used with the risk from each one being low, disguising the fact that the overall risk is high. With a semi-quantitative technique, it is not possible to add up a number of "lows" and, if a number of different cases all give "low", the possibility that the total risk is not "low" may be missed. If a large number of outcomes (say greater than six) are needed to either well-define the highest risk event, highest frequency or consequence event, or differentiate between the events being considered (with and without a risk reduction measure in place), then the technique is at the limits of its applicability and a more sophisticated quantitative risk assessment should be considered.

Semi-quantitative risk assessment also cannot be used to evaluate cumulative risks where the total risk arises from many different hazards, unless there is no interaction between the hazards. However, it can be used as a screening tool to identify those hazards or risk reduction measures that need to be considered for more detailed analysis, and in this case the risk ranking guidance applies.

B.2.2 Assessing Risk Reduction Measures

A key limitation of semi-quantitative risk assessments is that the bandings are broad (typically an order of magnitude), which means that there may be many cases where the benefits of a risk reduction measure cannot be seen. For example, the (real) consequence or frequency may be reduced, but the banding and hence (indicated) risk does not change, or where one of two risk reduction measures shows a decrease in risk banding whereas the other risk reduction measure may actually give the larger (real) risk reduction. These limitations need to be considered when making decisions using this technique.

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 the combination of frequency and consequence.

To use semi-quantitative risk analysis to assess whether a single risk reduction measure needs to be implemented for the risk to be ALARP, the cost of a risk reduction measure that is in gross disproportion to a particular safety benefit must first have been determined.

The technique can be used to determine which of two risk reduction measures should be implemented, if the difference in safety benefit 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 is provided by the semi-quantitative analysis, quantitative risk assessment may be needed to determine which one to implement.

The introduction of some quantification in the ALARP assessment 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 cannot differentiate between them, then quantitative risk analysis may be necessary to show the difference. However, where the potential consequences are more severe, or there is a need to assess the cumulative risk from many hazards, then semi-quantitative risk analysis is unlikely to be appropriate.

B.3 Quantitative Risk Analysis and Cost Benefit Analysis

Quantitative Risk Assessment (QRA) can be used to calculate the risk reduction achieved by a measure and, with cost benefit analysis (CBA), to determine whether it is reasonably practicable to implement the measure or not. General guidance on QRA including its use to compare to tolerability criteria is given in the PSF *Safety Case Requirements*; the following sections provide guidance on the use of QRA in ALARP assessments.

B.3.1 The QRA Technique

In a QRA, the frequency and consequence of a hazard are assessed in detail over the range of hazardous outcomes that could occur, in order to quantify both frequency and consequence, and thereby to calculate the risk. It therefore provides a much more detailed picture of the risks enabling the difference in safety benefits between different risk reduction measures to be assessed more accurately.

When assessing the benefit of a risk reduction measure, the QRA must include sensitivity analyses to gauge the potential for plausible changes in basic assumptions to invalidate the conclusions and decisions based thereon.

B.3.2 Assessing Risk Reduction Measures through QRA and CBA

Cost benefit analysis (CBA) is the quantitative assessment of the cost of implementing a particular risk reduction measure and the comparison with the safety benefit (risk reduction) 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 of the risk reduction measure divided by the risk reduction achieved (the reduction in Potential Loss of Life over the lifetime of the risk reduction measure); 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 are less likely to be grossly disproportionate and therefore the corresponding risk reduction measures more likely to be implemented because of lower costs, or greater risk reduction.

The Potential Loss of Life is defined to be the sum, across all hazardous events and scenarios being considered, of the average annual fatalities, where the average is calculated as the annual frequency of an event multiplied by the number of fatalities resulting from it.

A Defined ICAF criterion of at least **€3,100,000** is advised; this is at 2022 prices and is index-linked; an explanation of this figure is given in Appendix C. However, in using this figure in an ALARP assessment a range of factors, including sensitivity and uncertainty, need to be taken into account for the decision making process to be robust. It is for this reason that gross disproportion is required between the Calculated ICAF and Defined ICAF criterion before a risk reduction measure is rejected as not reasonably practicable.

B.3.3 Assessing Risk Reduction Measures through Ranking

The safety benefit provided by a risk reduction measure is the difference between the risk calculated with and without the risk reduction measure in place. The safety benefit per unit cost can then be determined in order to rank risk reduction measures. This ranking allows the most preferential risk reduction measures to be identified, but, apart from those for which the cost is clearly grossly disproportionate to the safety benefit, it does not identify the cut-off point in the ranking below which measures are grossly disproportionate (i.e. not reasonably practicable). To do this, the assessment of the risk reduction measure needs to use cost benefit analysis.

B.3.4 Gross Disproportion Factor

The Gross Disproportion Factor (GDF) is the factor between the Calculated ICAF and the Defined ICAF criterion. For a risk reduction measure to be judged not reasonably practicable, a GDF of at least 2 is essential and a robust justification is required for any value less than 10; an explanation of these figures is given in Appendix D. Thus, if the ratio between the Calculated ICAF and the Defined ICAF is less than the GDF, gross disproportion is not normally shown and the risk reduction measure must be implemented.

Appendix C. Defined ICAF

To assess reasonable practicability using CBA there is a need to set a Defined Implied Cost of Averting a Fatality (ICAF). This is compared to the Calculated ICAF, which is:

Calculated ICAF = Cost of measure / Reduction in Potential Loss of Life

The reduction in Potential Loss of Life is the reduction in product of the frequency and the consequences of events in terms of fatalities over the lifetime of the risk reduction measure.

For the purposes of the ALARP assessment, the CRU advises that a Defined ICAF of at least **€3,100,000** (at 2022 prices and index-linked) is used.

This value is based on an existing determination made by the Transport Infrastructure Ireland (TII), which is the only comparable figure that the CRU has identified as being used by another statutory agency in Ireland. TII has calculated accident costs and, at 2011 prices, the cost per fatality was calculated at €2,310,500 [2]. They also advise of annual growth factors, which gives the value of €3,069,000 in 2022 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 €3,100,000 is reasonably practicable. (Appendix D addresses gross disproportion).

By way of comparison with other jurisdictions, in the UK the HSE [3] set the value of a life at £1,336,800 in 2003, which is approximately €2,945,000 in 2022 (assuming £1 = €1.25 and the UK retail price index increases of the 20 year period).

Appendix D. Gross Disproportion Factor

In CBA, the Gross Disproportion Factor (GDF) is the minimum factor between a Calculated ICAF and the Defined ICAF (see Appendix C) such that the CRU will consider there to be gross disproportion between the cost of implementing a risk reduction measure and the safety benefit it provides. A value of at least 2 for the GDF is required, with a robust justification required to use a GDF of less than 10.

By comparison, the UK HSE advises a GDF 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.[4]

A robust justification is required for the use of a GDF below 10 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 technique, 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. In addition, the maximum cost of a risk reduction measure to be implemented at lower individual risks is extremely small. For example, for a risk reduction measure that reduces an individual risk of 10^{-5} per year by 10% for 10 people[5] over 10 years, the maximum cost of the risk reduction measure before it becomes grossly disproportionate to the risk reduction is €3,100 for a GDF of 10. Therefore, the CRU expects a robust justification if a GDF of less than 10 is used.

For petroleum, natural gas and LPG undertakings, the number of persons that may be exposed to any hazard is likely to be very low, far lower than say for the effects of a nuclear accident where a low risk may affect a very large number of people. Original work on the GDF in the UK was in relation to the nuclear industry and because of the large numbers of people involved, even a low individual risk may have led to a significant Potential Loss of Life and therefore justified significant spend even with a relatively low GDF. The CRU wishes to avoid a low GDF being used to justify the non-implementation of a relatively low-cost measure that has some safety benefit, but only to a small number of people whose individual risk is low. This supports the requirement for a robust justification of a GDF below 10. In addition, there are risk reduction measures that are required in order to meet Good Practice, where the factor between the cost and the safety benefit is well in excess of 10, indicating that consideration of well-known hazards and associated risk reduction measures has, in some cases, used GDFs well in excess of those proposed here. The addition of a spare lifeboat on an offshore platform is such an example.

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

[5] Note that this argument does not follow if a very large number of people may be affected by the hazard as may be the case for a nuclear accident. Nuclear power is outlawed in Ireland but forms the basis of the some of the UK risk regime, which explains some of the differences in the approaches.

Appendix E. Justification of Risk Tolerability Limits

E.1 Individual Risk

E.1.1 Risk Tolerability Limits

Individual risk is the risk to a single person. The Risk Tolerability Limits in Table 3 are advised.

	Upper Tolerability Limit (Fatalities per year)	Lower Tolerability Limit (Fatalities per year)
Worker	10^{-3}	10^{-6}
Public	10^{-4}	10^{-6}

Table 3: Individual Risk Tolerability Limits for workers and the general public

E.1.2 Comparison with Other Risk Limits in Ireland

The HSA paper on COMAH land use planning in Ireland [9] uses a risk-based methodology. For new establishments, a QRA must be submitted to the HSA, who will evaluate it before advising the planning authority. It must be demonstrated that the fatality risk to an individual is less than 10^{-6} fatalities per year to a member of the public, and $5x10^{-6}$ for a person at an "off-site" (i.e. unrelated) worksite, otherwise the HSA 'advises against' the proposed development.

E.1.3 International Comparison

For land use planning criteria in the UK, the HSE propose a broadly acceptable individual risk tolerability limit of one in a million (10^{-6}) fatalities per year. Similarly for land use planning in the Netherlands, safety distances have been defined in regulations based on an individual Risk Tolerability Limit of 10^{-6} fatalities per year. Risk tolerability limits, 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}) fatalities per year is therefore seen as an acceptable level of everyday risk for the general public.

The HSE policy document *Reducing Risks Protecting People* (R2P2) [4] gives a risk tolerability limit of 10^{-4} fatalities per year for people off-site (public).

HSE Offshore Information Sheet No. 3/2006 [5] and R2P2 give an individual risk tolerability limit of 10^{-3} fatalities per year for workers within the offshore industry, or other high risk industries.

E.2 Societal Risk

E.2.1 Risk Tolerability 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 7 shows the FN Curve advised in this document.

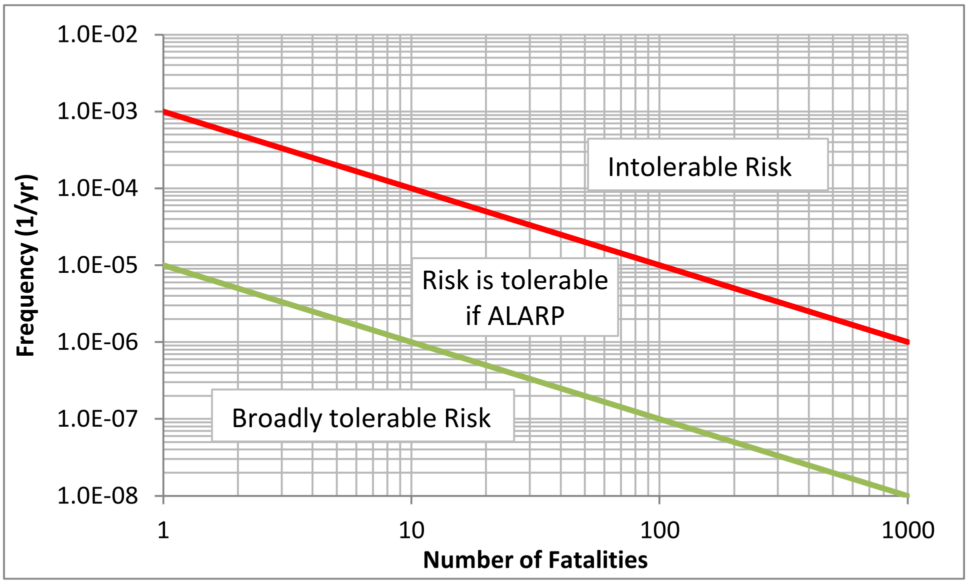

Figure 7: FN Curve showing the Risk Tolerability Limits for the public (excluding workers)

The FN Curve shown in Figure 7 provides guidance on what the CRU considers to be an appropriate societal Risk Tolerability Limit in relation to petroleum activities in Ireland in all but exceptional circumstances. Instances where any part of the FN Curve crosses the line such that the risk is intolerable will be considered on a case-by-case basis, which recognises the possibility that exceptional circumstances may arise where this is justified by other benefits (e.g. over-riding national interest). The societal Risk Tolerability Limits will be reviewed and, if necessary, revised in the future in the light of experience or to take account of changes in national or international practice.

For a pipeline, the above societal risk figures apply to 1.6km of pipeline.

E.2.2 Comparison with Other Risk Limits in Ireland

The HSA paper on COMAH Risk-based Land Use Planning in Ireland [9] gives an FN Curve that is an order of magnitude higher than that used by the CRU, such that, for example,

- The HSA 'advise against' planning approval for a risk of 1 in 5,000 years for 50 fatalities; and
- A risk of 1 in 100,000 years for 10 fatalities is the highest level that is broadly acceptable.

- Between the two lines, Operators and potential Operators will be required to demonstrate that, in relation to proposed changes, all reasonable efforts have been made to reduce the risk to a level that is as low as reasonably practicable. In the region between these two values, the planning authority is advised of that fact in order to take it into account in their planning decision.

The HSA values are higher than those in the FN Curve in Figure 7. However, the CRU and HSA societal Risk Tolerability Limits serve different purposes. The HSA Risk Tolerability Limits are applied using a screening approach for proposed developments in the vicinity of all top tier COMAH sites, and determine the advice given by the HSA in individual cases. The role of the HSA in land use planning is to advise local authorities on proposed developments and takes the form of 'advises against' or 'not advised against'. The CRU on the other hand is an accepting authority and , based on the safety case(s) submitted, will determine whether or not an Undertaking should be granted a safety permit. The CRU Risk Tolerability Limits provide guidance on what the CRU considers to be appropriate for petroleum, natural gas and LPG infrastructure in Ireland, in all but exceptional circumstances.

E.2.3 International Comparison

The UK HSE's R2P2 document defines a FN Curve with a slope of -1 passing through 50 fatalities with a frequency of 2×10^{-4} for maximum tolerable societal risk. In the UK, this figure includes workers at a hazardous site, whereas the CRU criteria in Ireland is for members of the public only.

A range of different societal risk tolerability limits are used worldwide. The limits proposed by the CRU differ from those of the UK HSE but are similar to those in use in some other countries. The FN Curve was specified following a process involving a review of international societal risk tolerability limits [6] and an extensive comparison exercise to test the application of the proposed limits to relevant examples of oil and gas installations, in the UK and other countries, and also high-level estimates of worldwide historical experience of accidents with large numbers of fatalities. As a result of this review, the selected FN Curve was considered appropriate and achievable for entities in Ireland within the regulatory remit of the CRU, noting that the limits apply to the public only and not to workers (an important distinction that has a strong influence on an FN Curve for lower values of N).