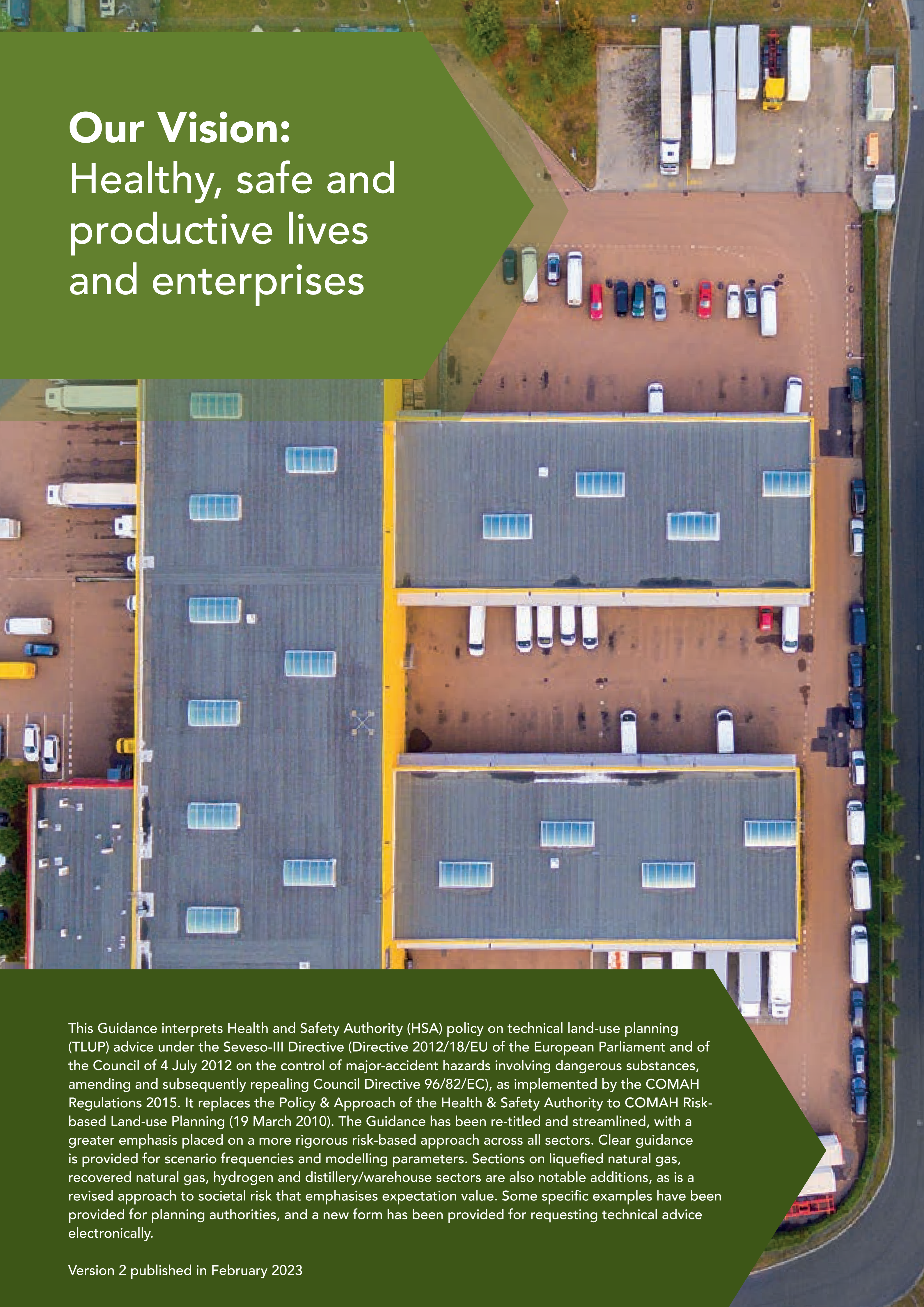
HSA

An tÚdarás Sláinte agus Sábháilteachta
Health and Safety Authority

Guidance on technical land-use planning advice

For planning authorities and COMAH establishment operators



Our Vision: Healthy, safe and productive lives and enterprises

This Guidance interprets Health and Safety Authority (HSA) policy on technical land-use planning (TLUP) advice under the Seveso-III Directive (Directive 2012/18/EU of the European Parliament and of the Council of 4 July 2012 on the control of major-accident hazards involving dangerous substances, amending and subsequently repealing Council Directive 96/82/EC), as implemented by the COMAH Regulations 2015. It replaces the Policy & Approach of the Health & Safety Authority to COMAH Risk-based Land-use Planning (19 March 2010). The Guidance has been re-titled and streamlined, with a greater emphasis placed on a more rigorous risk-based approach across all sectors. Clear guidance is provided for scenario frequencies and modelling parameters. Sections on liquefied natural gas, recovered natural gas, hydrogen and distillery/warehouse sectors are also notable additions, as is a revised approach to societal risk that emphasises expectation value. Some specific examples have been provided for planning authorities, and a new form has been provided for requesting technical advice electronically.

Version 2 published in February 2023

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Part 1

Part 2

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Part 3

Glossary of terms and definitions

ALARP	as low as reasonably practicable
ADAM	Atmospheric Dispersion Accident Model
BAT	Best Available Technique
BATC	Best Available Technique Conclusions
BLEVE	Boiling Liquid Expanding Vapour Explosion
BREF	Best Available Technique Reference Document
CBA	cost-benefit analysis
CCA	Central Competent Authority
CD	consultation distance
CDOIF	Chemical and Downstream Oil Industries Forum
CIA	Chemical Industries Association
COMAH	Control of Major Accident Hazards
cpm	chances per million (years)
EPA	Environmental Protection Agency
EV	expectation value
FGAN	Fertiliser Grade Ammonium Nitrate
Flash Point	the lowest temperature at which vapours above a volatile combustible substance ignite in air when exposed to flame
HSA	Health and Safety Authority
Flash fire	combustion of flammable gas/vapour/air mixture, no overpressure
FN curve	a cumulative frequency Vs number of fatalities curve (for societal risk)
HSE	Health and Safety Executive (UK)
LFL	lower flammable limit
LOC	loss of containment event
LUP	land-use planning
MATTE	major accident to the environment
NATECH	major accident initiated by a natural hazard or disaster
PADHI	planning advice for developments near hazardous installations
PIZ	Public information zone
PLL	potential loss of life
Pool fire	surface fire involving a pool of flammable liquid
QRA	quantified risk assessment
R2P2	Reducing Risks, Protecting People
SAC	Special Area of Conservation
SEP	Surface Emissive Power
SPA	Special Protection Area
TLUP	technical land-use planning
TOR	tolerability of risk
VCE	vapour cloud explosion

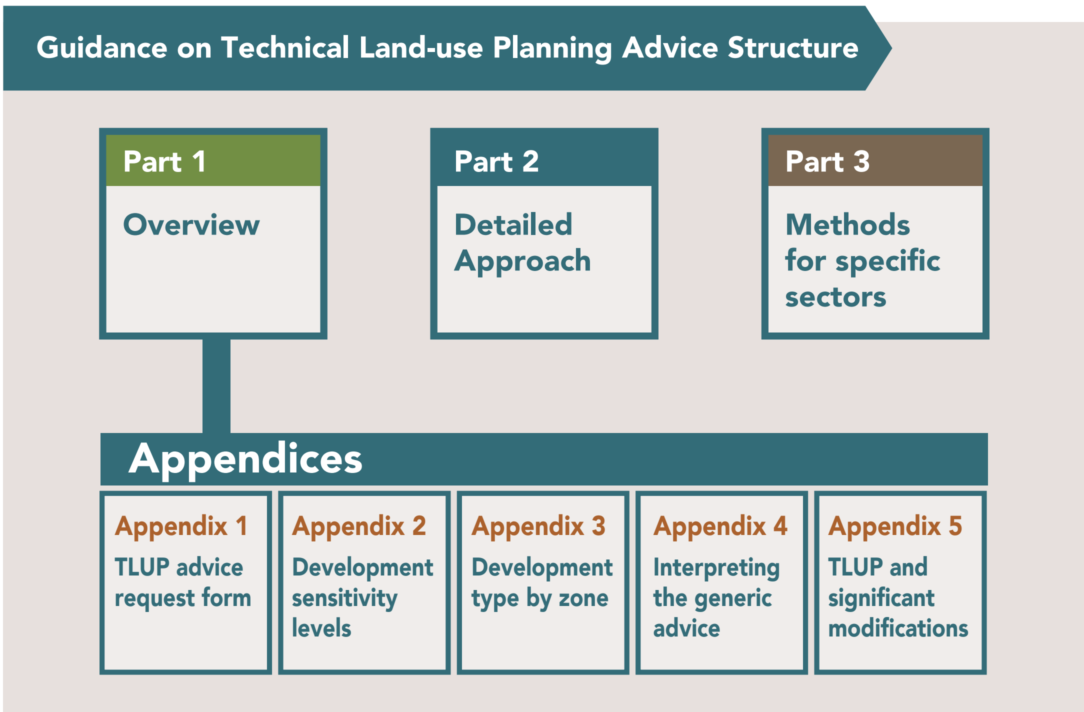
Executive summary

This Guidance interprets the Health and Safety Authority (HSA) policy on the technical land-use planning (TLUP) advice requirements of the Seveso-III Directive *(Directive 2012/18/EU of the European Parliament and of the Council of 4 July 2012 on the control of major-accident hazards involving dangerous substances,* amending and subsequently repealing Council Directive 96/82/EC), as implemented by the *Chemicals Act (Control of Major Accidents Involving Dangerous Substances) Regulations 2015*. The Guidance replaces the *Policy & Approach of the Health & Safety Authority to COMAH Risk-based Land-use Planning (19 March 2010).* This Guidance has been revised and reissued as version 2 published February 2023. The revised version includes an amended section 3.4 covering Hydrogen Installations.

The Guidance consists of three parts.

Part 1 introduces the approach:

- It describes the general background, as well as the risk criteria for new establishments and the nature of the generic advice that will be provided to planning authorities for developments in the vicinity of establishments.
- It explains how societal risk affects that technical advice.
- Section 1.7 explains where major environmental accidents fit into the framework, and it also describes the frequency of natural major accident initiators.
- Section 1.8 elucidates the purpose of the public information zone (PIZ).
- Section 1.9 explores the method that will be used to set the consultation distance (CD).
- Appendices 1 to 4 are closely linked to Part 1. Planners may find that, generally, they do not need to look beyond Part 1.



Executive summary (cont'd)

Part 2 includes these elements:

- The technical detail underpinning the establishment of the TLUP risk contours is described. Section 2.1 lists the sector groups for which TLUP criteria are being established.
- Risk of fatality and the use of probit equations is explained in Section 2.
- The derivation of fatality levels from exposure to thermal radiation is included in Section 2.3 and is expanded to address the issue of people residing/working inside structures in Section 2.4. This is followed by an assessment of overpressure effects on people residing/working inside or outside structures, as well as the effects on the structures themselves.
- Toxicity is addressed in Section 2.5, where a table of common probit equations is provided, along with indoor/outdoor fractions, weather stability sets, and modelling temperatures.
- Domino effects are discussed in Section 2.6.
- Pool fire parameters are explained in Section 2.7 and Section 2.8. Ignition probability is addressed in Section 2.9.
- More complex situations and approach limitations are explored in Section 2.10 and Section 2.11.

Part 3 sets out, for each of the sectors identified in Section 2.1, the scenarios that are to be modelled in order to generate the individual risk zones that form the basis of standard TLUP advice to planning authorities.

Non-technical summary

As a result of a global history of major accidents at locations where residential development was located too close to industrial sites with major accident hazards, the Seveso Directives introduced a requirement for controls on development to be put in place. This enables planning authorities to be technically informed on industrial accident risks before making decisions in relation to development near, or at, such locations.

The HSA is the statutory body providing TLUP advice in Ireland, which it does at the request of a planning authority.

This Guidance document explains in detail how the HSA will go about developing the required technical advice. It identifies sector types and explains, for each sector, the nature of accidents that will be considered, along with the scientific approach to estimating the likelihood of those accidents occurring.

As computer programmes of varied complexity can be employed to estimate both hazards and risks, the modelling parameters to be used are specified: these include the temperature of releases of dangerous substances from containment, wind speed, the proportion of people indoors, and the fatality thresholds for thermal radiation, overpressure and toxicity.

All of this enables lines of equal risk (isorisk) to be drawn on a map of the establishment and the surrounding area. Three such lines are provided in standard generic advice: these risk lines represent the chances, in a million per year, that a fatality will occur to a person permanently present at a location:

- 10 chances per million (cpm) of fatality
- 1 cpm of fatality
- 1/10th of 1 cpm of fatality.

More intensive and/or extensive development is increasingly 'not advised against' as the risk decreases. The development types potentially suitable for each risk zone are described in general terms in the body of the Guidance document and in extensive detail in Appendix 2 and Appendix 3.

As explained in the example in Appendix 4, it is possible to check whether a particular type of development is advised against, by locating it within the TLUP zones that have been provided to a planning authority on a map (via a Graphical Information System file) and using the information provided in the appendices.

Details are also provided on major accidents to the environment (MATTEs), and major accidents initiated by natural hazard or disaster events (NATECH). In addition, societal risk (risk of multiple fatalities), and how it will be taken into account in developing technical advice, is explained.

Part 1: Land-use planning (LUP) overview

1.2 General background

The Seveso-III Directive (2012/18/EU) requires that the objectives of preventing major accidents and limiting their consequences should be taken into account in land use policy.[1]

As implemented by the COMAH Regulations 2015[2], the objectives are to be achieved through controls on:

- the siting and development of new establishments,
- modifications to existing establishments,
- development in the vicinity of establishments.

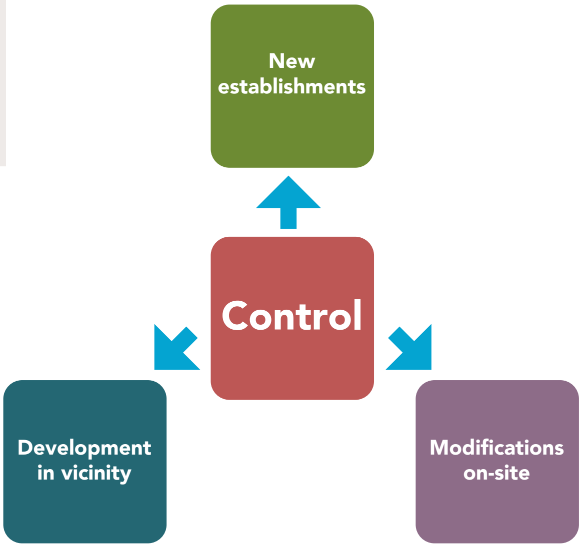


Figure 1: Achievement of the Seveso-III Directive objectives

In applying these controls, account must be taken of the long-term requirement to maintain appropriate distances between establishments and residential areas, buildings and areas of public use, major transport routes, recreational areas and areas of particular natural sensitivity or interest.

Publicly accessible technical advice must be available to a planning authority, on the off-site risk from an establishment, when decisions are being made in the planning process. The provision of this technical advice to a planning authority is referred to as 'technical land-use planning' or 'TLUP'.

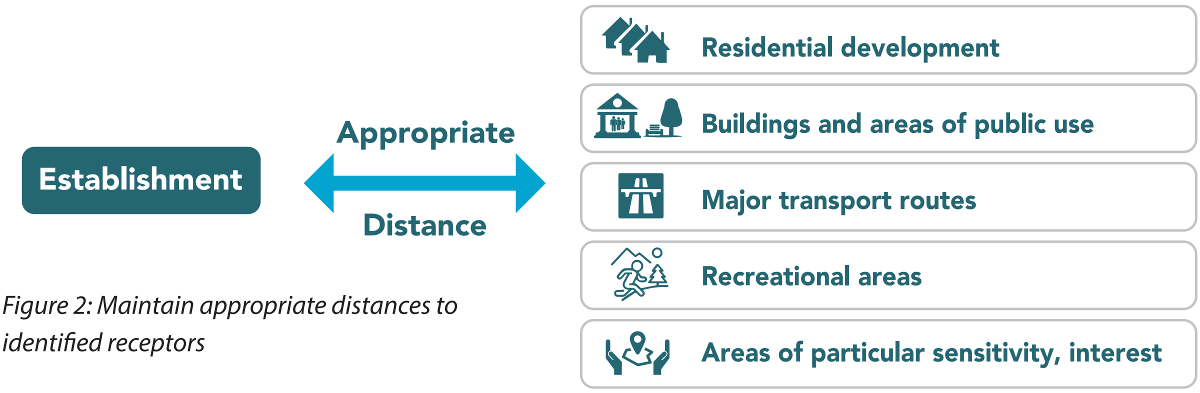


Figure 2: Maintain appropriate distances to identified receptors

[1] Article 13 of the Seveso-III Directive.

[2] Chemicals Act (Control of Major Accident Hazards Involving Dangerous Substances) Regulations 2015 (S.I. No. 209 of 2015)

This Guidance addresses the policy and practice of the Health and Safety Authority (HSA) in the provision of TLUP advice to planning authorities.

The Seveso-III Directive is implemented primarily under the Chemicals Act (Control of Major Accident Hazards Involving Dangerous Substances) Regulations 2015 (S.I. No. 209 of 2015): the 'COMAH Regulations 2015'. The TLUP requirements of the Directive are addressed by COMAH Regulation 24 (and also Regulation 12 for modifications to an establishment) and by the Planning and Development Regulations 2001 (S.I. No. 600 of 2001 as amended).

COMAH Regulation 24 allows the Central Competent Authority ('CCA') for the Seveso-III Directive, which is the HSA, to set and review a protective consultation distance (CD) around each establishment. This CD must be formally communicated to all relevant planning bodies. Planning bodies in turn are required to seek technical advice for any proposed development of the specified types (see Figure 3) within the CD.

When the CCA receives an appropriate valid formal request from a planning body (please refer to Appendix 1 for the Request for TLUP advice form), it is obliged by the COMAH Regulations to provide TLUP advice.

Figure 3: Planning authority must seek technical advice for specified developments

The Planning and Development Regulations set out the overall time frames for planning processes. Regulation 24 of the COMAH Regulations 2015 sets out the time frames within which the CCA must provide technical advice to a referring planning body. Planning bodies should allow for the time necessary for provision of TLUP advice by the CCA.

The Planning and Development Regulations specify the:

- circumstances in which planning authorities are to seek TLUP advice,
- information that must be supplied to the CCA when seeking TLUP advice.

1.3 Best practice in land-use planning

Best practice in TLUP advice systems is described in the European Guidelines on LUP[3] (see Section 4.3.1, pages 24 and 25 of those Guidelines). It advises that a TLUP advice system should apply the principles of:

- consistency ("Outcomes from broadly similar situations are broadly the same under similar conditions"),
- proportionality ("The constraint should be proportional to level of risk"),
- transparency ("Clear understanding of the decision-making process").

Best practice also requires that account be taken of the most recent relevant technical knowledge. The system of TLUP advice set out in this Guidance adheres to those principles and also takes into account the publication of the more recent *Handbook of Scenarios for Assessing Major Chemical Accident Risks*[4] and the provision of ADAM[5] software to CCAs by the Major Accident Hazards Bureau along with taking account of any relevant technical knowledge in the provision of TLUP advice.

The risk-based TLUP advice methodology set out in this Guidance will be used to develop the *ad hoc* TLUP advice required by the Seveso Directive as well as in the development of generic LUP zones around all establishments covered by the Directive. If the HSA engages an external body to draw up the generic LUP zones, the approach set out in this Guidance is to be followed. Under the COMAH Regulations 2015, provision of generic TLUP advice by the CCA is an activity chargeable to COMAH operators as explained on the COMAH section of the Authority's website.

1.4 Advice on new establishments

COMAH Regulation 24 refers to the siting and development of new establishments[6]. In this context, new establishments include existing operations that intend to increase their inventory above the COMAH threshold (thereby bringing them within the scope of COMAH) as well as newly-constructed COMAH establishments.

Planning applicants for new establishments are expected to provide sufficient information to enable the CCA to apply the methods set out in this Guidance, so that the technical advice may be generated for planning authorities.

In keeping with the longer-term aims for LUP under the Seveso Directive, technical advice in relation to new COMAH establishments will be more stringent than that which applies to existing COMAH establishments. The individual location-based risk contours for **new** establishments, not to be exceeded, are shown in Table 1.

1×10^{-6}/year	• Maximum tolerable risk to a member of the public
5×10^{-6}/year	• Maximum tolerable risk to a person at an off-site work location

Table 1: New establishment criteria

[3] MAHB (2008). Land Use Planning Guidelines in the Context of Article 12 of the Seveso II Directive 96/82/EC as amended by Directive 105/2003/EC. EC, Brussels

[4] Handbook of Scenarios for Assessing Major Chemical Accident Risks. Available at: **https://minerva.jrc.ec.europa.eu/en/shorturl/minerva/handbook_of_scenarios_for_assessing_major_chemical_accident_risksonlinepdf**.

[5] Accidental Damage Analysis Module (**https://adam.jrc.ec.europa.eu/en/adam/content**).

[6] New establishment is defined in COMAH Regulation 2. It includes an establishment that enters into operation or is constructed on or after 1 June 2015, or a site of operation that falls within the scope of the Regulations, or a lower-tier establishment that becomes an upper-tier establishment, or vice versa, on or after 1 June 2015, due to modifications to its installations or activities resulting in a change in its inventory of dangerous substances.

When the individual risk criteria in Table 1 are met for a specific development, a societal risk evaluation may also be necessary (see Section 1.7).

Note: The CCA may also advise the planning authority to consult with the principal response agencies (An Garda Síochána, fire and ambulance services) in relation to emergency planning and response arrangements.

1.5 Advice on Significant Modifications to an establishment

The approach of the CCA to significant modifications has already been addressed in the *Guidance on 'Significant Modifications' Under the COMAH Regulations* (published in 2019 and available on the COMAH pages of the Authority's website).[7]

In summary, the CCA regulates the on-site risk element, setting limits for the tolerable level of risk increase that will be permitted and then, generally, requiring the lowest level of increased risk through the use of additional technical measures.

For off-site risk, the referral trigger is an off-site location fatality risk equal to or greater than 1×10^{-6} (per year). It will then be referred to the planning authority, with technical advice consistent with the advice framework given in Section 1.6 on developments in the vicinity of COMAH establishments.

The HSA must always be notified by operators in advance of any planned significant modification and the procedures outlined in the *Guidance on 'Significant Modifications' Under the COMAH Regulations* must be followed, irrespective of whether or not a modification will be subject to a planning application. The CCA will rely on the technical information in a valid significant modification assessment when providing technical advice to a planning authority – see Appendix 5.

1.6 Generic advice on developments in the vicinity of an establishment

Within the CD around each COMAH establishment, as notified to the planning authority, three zones of risk are plotted. These are based on the location, quantity and hazards of the dangerous substances present (taken from the formal notification required by Regulation 8 of the COMAH Regulations), according to the methodology set out in Part 2 of this document, which is further elaborated on for each sector in Part 3.

The individual risk zones to be plotted on a map are shown in Table 2.

10^{-5}/year	• Risk of fatality for inner zone (Zone 1) boundary
10^{-6}/year	• Risk of fatality for middle zone (Zone 2) boundary
10^{-7}/year	• Risk of fatality for outer zone (Zone 3) boundary

Table 2: Risk zones for TLUP advice

[7] https://www.hsa.ie/eng/your_industry/chemicals/legislation_enforcement/comah/significant_modifications/guidance_on_significant_modifications_under_comah_regs.pdf

Associated with these zones are four levels of development, with increasing sensitivity to major hazards. These are shown in Table 3.

Level	Development type
Level 4	Very large or sensitive development
Level 3	Development for use by vulnerable people
Level 2	Development for use by the general public
Level 1	Workplaces, Car parks

SENSITIVITY

Table 3: Development types (expanded on in Appendix 2 of this document)

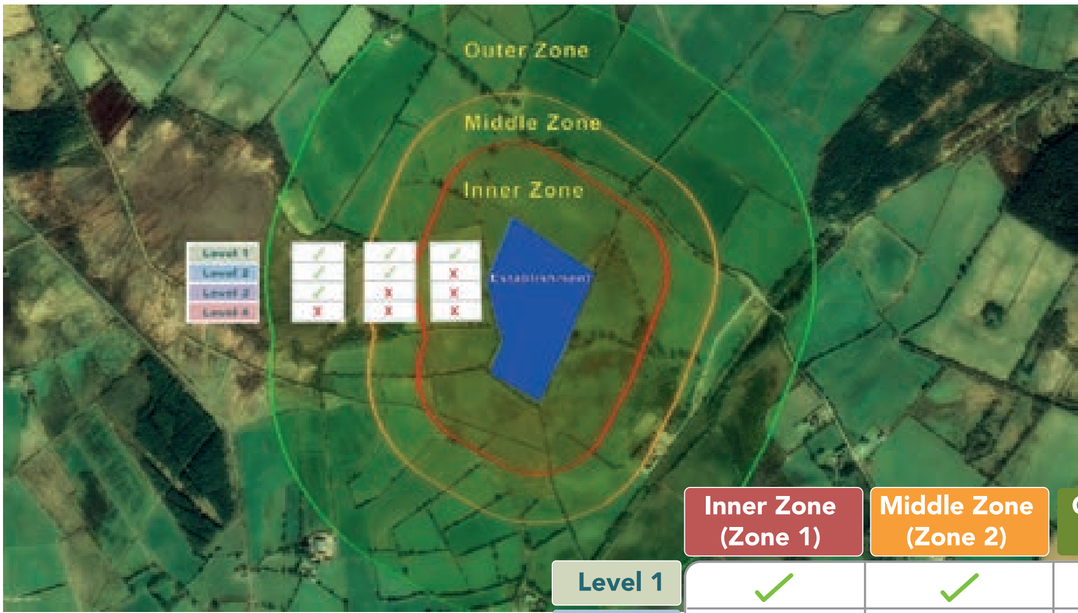
Broadly, the competent authority's generic technical advice to planning authorities takes the form of 'Advises against' (✗) or 'Does not advise against' (✓) as illustrated in Table 4 (based on the Planning Advice for Developments near Hazardous Installations (PADHI) (Health and Safety Executive, UK, 2021), elaborated on in Appendix 2):

	Inner Zone (Zone 1)	Middle Zone (Zone 2)	Outer Zone (Zone 3)
Level 1	✓	✓	✓
Level 2	✗	✓	✓
Level 3	✗	✗	✓
Level 4	✗	✗	✗

Table 4: Nature of TLUP advice provided for each zone

Therefore, for example, 'Developments for use by the general public' (Level 2) would be advised against in the inner zone, but not in the other zones. (Appendices 2 and 3 provide more detail on how developments fit into the matrix.)

A fictional contour map illustrates this:



	Inner Zone (Zone 1)	Middle Zone (Zone 2)	Outer Zone (Zone 3)
Level 1	✓	✓	✓
Level 2	✗	✓	✓
Level 3	✗	✗	✓
Level 4	✗	✗	✗

Figure 4: Generic TLUP advice zones and compatible development levels

Generic TLUP advice generated by the CCA and provided to planning authorities will form part of the relevant public planning file.

1.7 Societal Risk

A system based on the computation of individual risk has been outlined up to this point; that is, the risk to a (possibly hypothetical) person permanently located outside the establishment. The advice matrix (Table 4 and Appendix 2) takes account, to a degree, of group risk and the varied receptor sensitivities. It is applicable for the specified developments (listed in Appendix 2) that are located near a single COMAH establishment, and where the existing societal risk is well within the tolerable limit. However, there are times when the risk of multiple fatalities from an accident – societal risk – should be taken into account more explicitly. For example, this may include where an application relates to a proposed significant off-site population density, or where there is already a significant population residing/working within the risk zone, or where the risk is emanating from more than one establishment.

To take account of societal risk in such situations, the CCA will initially obtain an estimate of the expectation value (EV).[8] For example, for a frequency of occurrence of an accident at one chance in one million years (=1 cpm) fatally affecting 120 people, the EV is the product of the two, that is, 120. However, if the frequency of occurrence of the accident is increased to once in one hundred thousand years, then in order to maintain the same EV, the number of people affected must drop to 12 ($10 \times 12 = 120$).

EV will be relevant for TLUP advice concerning new COMAH establishments, for development near such establishments, and for significant modifications[9] to existing COMAH establishments where the risk or consequence is predicted to significantly increase.

[8] EV is the product (multiplication) of accident frequency, expressed in chances per million, and the number of people suffering fatality in that accident.

[9] For significant modifications, an increase in EV has already been flagged as the trigger for more detailed analysis in the *Guidance on 'Significant Modifications' Under the COMAH Regulations.* Health and Safety Authority (2019).

HSE 2001[10] provides an upper limit value for an intolerable societal risk criterion: for a predicted accident occurring no more frequently than once in 5,000 years, there should be no more than 50 fatalities. This has gained international acceptance as an anchor point for a line (of slope -1) to create an intolerable societal risk criterion for single accidents. HSA Guidance *Policy & Approach of the Health & Safety Authority to COMAH Risk-based Land-use Planning (19 March 2010)* recommended using points at (200 cpm / 50 fatalities) and (1000 cpm/10 fatalities) to create that line. An acceptable societal risk single risk criterion line can then be drawn at frequencies that are two orders of magnitude below the intolerable line (so a frequency of 1×10^{-4} on the intolerable line becomes 1×10^{-6} on the acceptable line).

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.

Some establishments will have the potential for fatalities to arise from a multiplicity of accident scenarios (or there may be other establishments in the vicinity, adding to the EV). In such situations, the total off-site EV should not exceed the criterion upper limit EV of 10,000. **Between EVs of 100 and 10,000, it should be demonstrated that all practicable efforts have been made to reduce the risk to a level that is as low as reasonably practicable (above a developmental EV level of 450, an FN curve[11] will be required as part of the demonstration).**

For new developments near an establishment, where the calculated off-site EV at the development is greater than 2,000, further assessment of societal risk will be required and the creation of an FN curve and calculation of the total EV will be necessary.

Where the EV exceeds 10,000, the TLUP advice to the planning authority will always be 'Advises against'.

Especially large-scale or sensitive development within the CD[12] will likely require a societal risk evaluation.

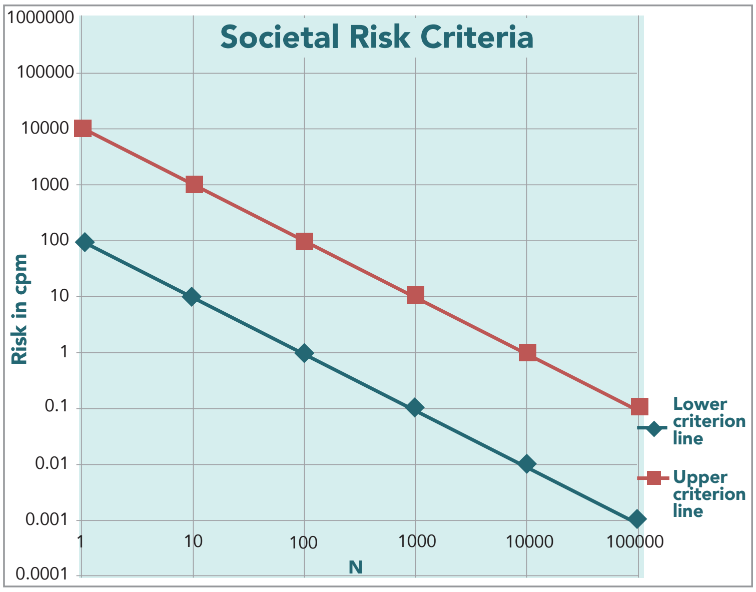


Figure 5: Upper and lower societal risk criterion lines (log scale)

[10] *Reducing risks, protecting people: HSE's decision-making process*, HSE Books, 2001. Paragraph 136 (on page 47): The HSE proposes that the risk of an accident causing the death of 50 people or more in a single event should be regarded as intolerable if the frequency is estimated to be more than once in 5,000 years.

[11] An FN curve is a plot of cumulative frequency versus consequences (expressed as number of fatalities).

[12] Consultation distance (CD) is the distance which was communicated to the planning authority by the CCA at the time of notification or subsequently. See also Section 1.9.

The societal risk criterion is applied i**n addition to** the individual risk criteria previously outlined.

Both the individual and societal risk criteria must be satisfied when considering new development, population intensification or significant modification. If the individual risk criterion is met, then the societal risk level has to be considered. If the societal risk is within the 'as low as reasonably practicable' (ALARP) region, then an FN curve should be generated to evaluate the societal risk level (using the relevant scenarios outlined in Section 3 of this document).

1.8 Environment and LUP

Article 13 of the Seveso Directive requires European Union member states to take account of the need, in the long term, to maintain appropriate distances between establishments and recreational areas/areas of particular natural sensitivity or interest (amongst others). A separation distance for environmental purposes will be considered appropriate if it is sufficient to enable the operation of suitable control and mitigation measures, and/or is such that the risk of serious environmental damage is low.

In the context of LUP, the prevention of MATTEs will be the primary objective and it is expected that accident pathways will be prevented. Where this is not practicable, or in the context of significant modifications at existing COMAH establishments, the assessment of major accidents to the environment focuses on the specific risks to sensitive receptors within the local environment, the extent of consequences to such receptors and the ability of such receptors to recover: environmental damage may be relatively long-lasting but is not necessarily irreversible. Recovery of habitats within a reasonable period of time is possible, depending on the dangerous substance involved. This information is weighed up when providing advice.

While the system described in the previous sections of this document focused on the risk to human health, it may also be applied to other environmental receptors, with a modification factor if necessary, in simple cases of airborne toxic releases or for the physical effects of fire and explosion. However, for accidental releases into waterways and in general, where the environmental receptors are more sensitive than human receptors, a different approach is taken.

Emphasis is initially placed on the prevention phase, the control of potential pollution routes and available response measures, rather than on the development of a quantitative risk assessment approach and use of risk-based criteria.

Assessment is based on a Source-Pathway-Receptor model. For new establishments, the CCA will focus on the removal of accident pathways to receptors (through the use of additional technical measures: appropriate containment, within the confines of current good practice and ALARP, for example). For significant modifications, the risk-based approach developed by the Chemical and Downstream Oil Industries Forum (CDOIF)[13] and outlined in the *Guidance on 'Significant Modifications' Under the COMAH Regulations* will be used.

Technical advice to a planning authority will address only the potential effects of major accidents, not routine environmental emissions. Routine environmental emissions associated with the operation of an establishment are a matter for the local authority or the Environmental Protection Agency (EPA), as relevant, and are subject to their permitting/licensing requirements.

[13] Chemical and Downstream Oil Industries Forum publication: *Guideline on Environmental Tolerability for COMAH Establishments, v2.0*

Irrespective of whether the approach is qualitative or quantitative, the following are considered:

- environmentally sensitive areas in the vicinity,
- presence of endangered species,
- protected water resources/biospheres,
- types of accident that can cause environmental damage (firewater run-off, for example),
- contamination routes (watercourses, for example),
- measures in place to protect the environment and their reliability,
- hard/reliable measures in place to contain run-off in the context of internal and external emergency plans,
- recovery periods with and without intervention,
- clean-up and remediation plans and resources, and
- if necessary, tolerability of assessed risk.

Under COMAH, operators are required to use best practicable means, specifically:

- to prevent a major emission of dangerous substances resulting from uncontrolled developments in an establishment into the environment, and
- for rendering harmless and inoffensive the substances emitted.

The approach of the HSA, therefore, is to examine potential effects on the environment from the identified credible major accident hazards and to satisfy itself that appropriate 'best practicable means' are/will be in place to prevent such effects. Best practicable means may constitute adequate bunding for storage tanks containing dangerous substances for example, allied with tertiary containment to prevent migration off-site of any overtopping fraction or contaminated firefighting water.

Detail on the modelling and assessment of major accidents affecting the environment is contained in the HSA's *Guidance to Inspectors on the Assessment of Safety Reports under the COMAH Regulations 2015* (HSA, 2017).

The potential for a major accident to be initiated due to natural phenomena (NATECH) is also considered.

Therefore, for example, the effect of flooding, lightning, storm damage, and subsidence is considered in relation to the potential effect on storage tanks and storage areas, as well as on important site utilities. For new establishments, operators must demonstrate that other potential initiators have been considered and that appropriate prevention/control/mitigation measures will be employed.

The following events should be assessed in relation to their potential to cause or increase the likelihood of a major accident:

NATECH event	Frequency (per year)
Storm	1 in 100-year event[14]
Snow	1 in 100-year event
Flood	1 in 1,000-year (river or coastal) event

Table 5: Frequency of naturally occurring potential initiators of major accidents (source in footnote [14])

For environmental hazards, good practice can be found in published sources, including relevant guidance from Best Available Technique (BAT) reference documents (BREFs) and the associated BAT conclusions (BATC) documents.

While the 'best practicable means' standard is also applied to the control of gaseous loss of containment (LOC) events (such as suitably sized catch pots for runaway reactions), the consequences of such releases are examined as part of the general major accident scenarios for human receptors.

Where detailed risk assessment is necessary, the risk levels to be attained for new COMAH establishments in relation to MATTEs (based on the CDOIF methodology) are shown in Table 6.

MATTE type	Broadly acceptable risk less than
A	1×10^{-4}
B	1×10^{-5}
C	1×10^{-6}
D	1×10^{-7}

Table 6: Broadly acceptable risk levels for MATTEs

For sites storing dangerous liquids in bulk, which will often be located near sensitive marine environments, such as Special Areas of Conservation (SACs) and Special Protection Areas (SPAs), the prevention of a major emission into the environment will be achieved through the use of appropriate primary, secondary and tertiary liquid containment.

A lower frequency of loss (see Section 3.6.6, Table 50) will be used for double containment tanks, to reflect their contribution to prevention of damage to the environment; new establishments will be encouraged to avail of this, or equivalent, technology.

Appropriate bunds, for containing spilled liquid and any applied extinguishing or cooling media, will be required. The general requirement is for 110% of the largest tank, or 25% of the total tank volume, where more than one tank exists in the bund, whichever is the larger figure. EPA guidance on firewater retention (EPA, 2019) is relevant in this context.

Tertiary containment will be required where overtopping with potential to cause a MATTE is a credible event.

[14] *Technical Rule on Process Safety 320: Precautions and Measures against the Hazard Sources Wind, Snow Loads and Ice Loads, 2015*, German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety.

Useful information to assist in MATTE assessment can be obtained from many sources:

Information on flood mapping for the 1 in 1,000-year return period is available at: https://www.floodinfo.ie/

Historical rainfall information from Met Eireann is available at: (https://www.met.ie/climate/services/rainfall-return-periods)

Environmental mapping information and COMAH establishment location data are available in the Environmental Sensitivity Mapping (ESM) Webtool: https://enviromap.ie/

A national resource for environmental information is available at: https://www.epa.ie/environment-and-you/climate-change/what-is-epa-doing/climate-ireland/

Some historic wind gust storm data have been published, as shown in Table 7.

Location	Gust (knots)
Belmullet	93
Birr	85
Casement	81
Claremorris	96
Clones	87
Cork Airport	94
Dublin Airport	75
Kilkenny	77
Malin Head	98
Mullingar	79
Roches Point	86
Rosslare	87
Shannon Airport	93
Valentia	88

Table 7: Historic wind gust data (Sweeney, 2000)[15]

To reflect the currently unquantified increased effect from climate change, the gust figures in Table 7 should be multiplied by 1.2 for TLUP advice purposes.

[15] Source: *A three-century storm climatology for Dublin 1715–2000,* John Sweeney, Department of Geography, National University of Ireland, Maynooth.

1.9 Public information zone

Prior to the COMAH Regulations 2015, the 'specified area' was defined as an area at greater risk of being affected by a major accident and within which an upper-tier establishment had to supply information directly to persons in the area on the appropriate action to take in an emergency. While this area still exists, it is no longer referred to as a 'specified area'. The requirement to provide this information still applies under the COMAH Regulations 2015, but the area is now to be known as the **Public Information Zone (PIZ)**. This will, at a minimum, coincide with the outer LUP zone. The HSA will use its discretion as to whether it should be enlarged further, based on the consequences of the identified major accident scenarios.

Existing specified areas will continue in use as the PIZ until they are replaced, which will happen as generic LUP advice for each establishment is rolled out to planning authorities. HSA's previous position paper *Setting the specified area* (HSA 2003), no longer applies.

1.10 Consultation Distance

A consultation distance (CD) is a distance around an establishment, within which there are potentially significant consequences from major accidents to people (or to the environment). The CAA notifies the planning authority of this distance. Historically, it has been set based on generic categories and distances in the planning and development legislation. Under the COMAH Regulations 2015, the CCA is required to review and update this advice as necessary and it is now supplied as a contour map file, which takes account of actual establishment notification data and related major accident risk. A review of the CD of every establishment was completed in 2021 and all planning authorities have been supplied with updated map data.

New establishments will be required to propose an appropriate CD to the CCA, in accordance with the methodology set out in this document and submit it to the planning authority as part of a planning application.

When establishing new CDs (or revising previously communicated CDs) the risk-based approach described in Part 3 of this document will be used to obtain a 1×10^{-9} (1 in a billion) fatality risk contour. Consequences to the thresholds specified in Section 2 will also be obtained. The CD will be set at the discretion of the CCA.

1.11 Future Technical updates

The CCA may update the technical details in Part 3 of this document from time to time, as necessary. All changes will be captured in a change log within the Guidance document and published on the HSA website.

Part 2: Detailed technical approach

2.1 Sectors

COMAH establishments can be treated as being in distinct sectors, each of which has characteristic dangerous substances and types of major accident. The sectors are:

1) Liquefied petroleum gas (LPG) installations
2) Liquefied natural gas (LNG) installations
3) Renewable natural gas (RNG) installations
4) Hydrogen installations
5) Natural Gas pipelines (within an establishment)
6) Flammable liquid storage installations
7) Fertiliser storage installations
8) Dangerous substance warehouses
9) Chemical/Pharmaceutical installations
10) Gas drum and cylinder installations
11) Explosives handling/storage installations
12) Ammonia refrigeration plant
13) Distilleries and spirit maturation warehouses

For each of these, a method for generating generic TLUP risk zones is elaborated on in this Guidance. Part 3 describes in detail how the generic advice will be generated, setting out the major accident scenarios, their frequencies, and the consequences to be considered. In Part 2 the technical background underpinning Part 3 is described.

2.2 Risk of fatality and the use of probit equations

The analysis requires an identification of credible major accident scenarios, followed by the likely accident consequences in terms of fatality. TLUP zones extend to a 1×10^{-7} per year fatality contour; therefore, any scenario that can contribute to this risk level should be considered. To estimate the fatal consequences of major accidents, established probit[16] relationships for fatality are used: they are conservatively derived and help to ensure consistency in approach, resulting in a risk-based analysis that is robust and transparent.

Fatality risk increases as the level of consequence (increased concentration/intensity of effect and duration of exposure) increases. The relationship between the consequence level and the probability of fatality can be characterised by a probit relationship. A range of consequences can be expected in a population exposed to an acute hazard (dose) which can be represented mathematically by a dose-response curve, with the number of people suffering fatal effects being the response. For computational purposes, it is better to fit the relationship into the form of a straight line. Probit equations do this and can be used to estimate the proportion of a population that may be affected by exposure to a particular harm.

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[16] Probit-based models, derived from experimental dose-response data, are often used to estimate the health effect that might result based on the intensity and duration of an exposure to a harmful substance or condition (for example, exposure to a toxic atmosphere, or thermal radiation).

Examples of probits are given in Table 8:

Chlorine toxicity	• Probit = -4.81 + 0.5 ln ($C^{2.75}t$) with concentration, C, in ppm and time (t) in minutes
Thermal radiation	• Probit = -14.9 + 2.56 ln ($I^{1.33}$ t) with intensity, I, in kW/m^2 and time (t) in seconds
Overpressure	• Probit = 1.47 + 1.35 ln (P) with pressure, P, in psi

Table 8: Examples of probit equations

The number value obtained from the probit equation can be looked up in a reference table to calculate the percentage of the population fatally affected. A probit of 5 corresponds to 50% fatality; a probit of 2.67 to 1% fatality; a probit of 7.33 to 99% fatality, and so on. Therefore, probit functions enable a consistent and transparent estimation of the fatality percentage in a standard exposed population.

The following sections will describe the probit equations to be used for estimating the consequences of specific types of major accident.

2.3 Consequences of thermal radiation

Thermal radiation exposure arises from fire-type events. Accidents that give rise to a thermal (heat) effect will impact differently on indoor and outdoor populations.

2.3.1 THERMAL EFFECTS ON PEOPLE OUTDOORS

The probit used for determining the fatality percentage of a population exposed to thermal radiation was developed by Eisenberg *et al.* (1975):

Probit = -14.9 + 2.56 ln ($I^{1.33}$ t)

(with I in kW/m^2 and t in seconds: I is the incident heat flux and t the exposure duration).

This relationship applies to a population out in the open when exposed to thermal radiation.

For fires of long duration, such as pool fires and jet fires, it is reasonable for TLUP calculations to make allowances for the fact that, unless incapacitated, people will retreat from the hazard source. Therefore, the exposure time is the time required to reach a safe place. In the *Policy & Approach of the Health & Safety Authority to COMAH Risk-based Land-use Planning (19 March 2010)*, the default exposure time was assumed to be 75 seconds at the maximum heat flux. This figure was broadly based on the approach of the UK Health and Safety Executive, but it neglected to take account of the diminution of effects by people escaping from the source, as the UK Health and Safety Executive approach did. Having also examined the approach taken in RIVM (2020) which allows for a much shorter exposure time of 20 seconds (with an associated very conservative probit), the default exposure has been reduced to 60 seconds.

Using those parameters, the Eisenberg probit relationship implies the following fatality percentages at the heat flux levels shown in Table 9:

8.02 kW/m²	• 1% fatality
10.9 kW/m²	• 10% fatality
15.9 kW/m²	• 50% fatality

Table 9: Heat flux and fatality levels, outdoor, for a 60-second exposure

For TLUP, the threshold of a fatality flux level of 8.02 kW/m² can be used as a screening distance for consequence modelling, in line with the methodology described in this document.

For flash fires, fatality levels of 100% are assumed inside the lower flammable limit (LFL) envelope, with 0% fatalities outside that envelope.

2.3.2 THERMAL EFFECTS ON PEOPLE INSIDE BUILDINGS

People inside buildings will have some protection from the effects of incident thermal radiation. Therefore, a further refinement of the model is necessary. For people indoor, the relevant thermal radiation thresholds[17] are:

>25.6 kW/m²	• Building conservatively assumed to catch fire quickly, and therefore there is a 100% fatality probability.
<25.6 kW/m²	• People are assumed to have escaped outdoors, and therefore have a risk of fatality corresponding to that of people outdoors.
<12.7 kW/m²	• People are assumed to be protected, and therefore there is a 0% fatality probability.

Table 10: Heat flux levels relevant for people within buildings

For flash fire, within the flash fire envelope, indoor fatality levels are conservatively assumed to be 10%.

2.3.3 THERMAL EFFECTS AND PROPERTY DAMAGE

Property damage may be a relevant element of the technical advice provided to a planning authority: the Seveso Directive requires appropriate distances to be maintained to "buildings and areas of public use". A mechanism is required to take into account the risks (including economic) to property, structures, and businesses as part of any TLUP advice, where relevant (see also Section 2.4.3).

The presence of physical blocking structures can be taken into account when determining the areas that are likely to be subject to thermal radiation.

[17] Source: Crossthwaite *et al.* (1988)

For thermal radiation, the key contours for structural damage[18] will be:

37.5 kW/m²	• Sufficient to cause damage to process equipment
25.6 kW/m²	• Minimum heat flux to ignite wood at indefinitely long exposures (non-piloted)
14.7 kW/m²	• Minimum heat flux for piloted ignition of wood, melting of plastic tubing

Table 11: Heat flux levels and property damage

2.4 Explosion overpressure

The explosion overpressure effects in the standard model relate to vapour cloud explosions (VCEs). This refers to concentrations of flammable gas or vapour released into confined areas, which then find an ignition source. The TNO multi-energy method (TNO 1992) is used to estimate the level of overpressure from such events. The flammable volume must be determined as well as the confined volume in the congested area. Explosion Strength 7 is applied to the confined volume and Explosion Strength 2 to the unconfined volume. Sometimes there will be no confined volume, but typically it is in the immediate area of the release, where there are many vessels or other obstacles.

Typically (methods for specific sectors set out in part 3), 20% of the stoichiometric cloud volume is assumed to be in the congested area – if there is one – (where the ignition is assumed to occur) and is assigned Strength 7. If the actual confined volume is bigger than this, then the actual confined volume is used.

2.4.1 OVERPRESSURE EFFECTS ON PEOPLE OUTDOOR

The probit used for determining consequences from blast overpressure was developed by Hurst *et al*. (1989). The relationship is:

$$\text{Probit} = 1.47 + 1.35 \ln(P)$$

with P in psi (Note: 1 psi = 68.947573 mbar).

This relationship applies only to people exposed to blast overpressure outdoor and implies the following relationship between overpressure and fatality:

2.44 psi (168 mbar)	• 1% fatality
5.29 psi (365 mbar)	• 10% fatality
13.66 psi (or 942 mbar)	• 50% fatality

Table 12: Overpressure fatality thresholds for people outdoor

Caution: *This probit relationship should not be used for assessing the risk to indoor populations, as it fails to take any account of factors such as building collapse, and therefore could lead to a significant underestimation of the risk.*

Blasts also have the potential to generate projectiles, possibly capable of travelling several hundred metres. However, the available evidence is that the risk of a particular area being hit by a projectile is usually extremely low and is therefore generally not taken into account when using the methodology specified in this document.

[18] World Bank, 1985

2.4.2 BLAST EFFECTS ON PEOPLE INSIDE BUILDINGS

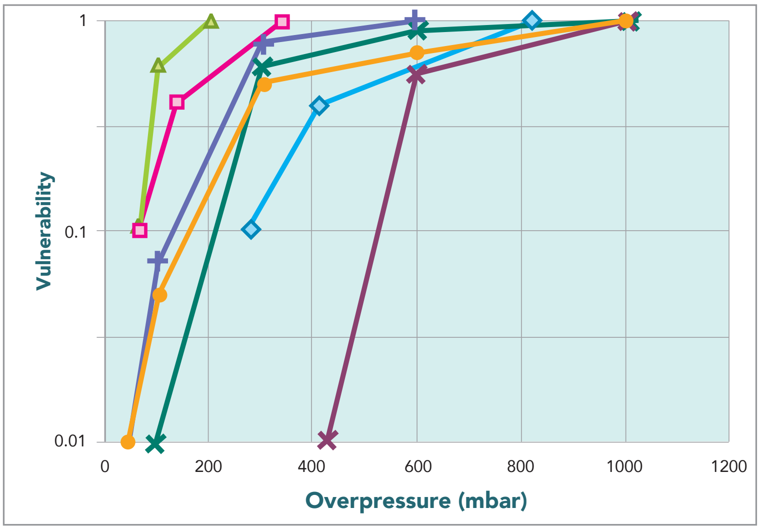
People indoors could be either more or less vulnerable to the effects of blast overpressure, depending on the blast resistance of the surrounding structure. The UK Chemical Industries Association (CIA) (Chemical Industries Association, 2020) published details of relationships between the risk of fatality for occupants and the level of blast overpressure for four different categories of building. The building categories are set out in Table 13.

Category 1	• Hardened structure building
Category 2	• Typical office block
Category 3	• Typical domestic building
Category 4	• Portacabin-type timber construction

Table 13: CIA building categories

The curves are reproduced in Figure 6. The CIA Category 3 Curve (typical domestic building: two-storey, brick walls, timber floors) will in most circumstances provide a reasonably conservative basis for assessing the risk of fatality to most residential populations, and is widely used for this purpose.

The curve will be applied as a first approximation in estimating fatalities within structures (the curves may not be conservative in every situation, which may sometimes necessitate a different approach).



Graph Key:

- CIA 1: Hardened structure building: special construction, no windows
- CIA 2: Typical office block: four story, concrete frame and roof, brick block wall panels
- CIA 3: Typical domestic buildings: two story, brick walls, timber floors
- CIA 4: Portacabin: timber construction, single story
- API B5: Reinforced concrete or reinforced masonry shear wall building
- API B3: Unreinforced masonry bearing wall building
- API B1, B2, B4: Wood frame trailer or shack, steel-frame/metal siding or pre-engineered building, steel or concrete reinforced masonry infill or cladding

NOTE-Building key items 1 - 4 are defined by CIA; items B1 - B5 are defined by API RP 752 (2003) [5, 3].

Figure 6: Vulnerability of people in Buildings, taken from a European Industrial Gases Association publication[19]

[19] European Industrial Gases Association, 2014: *Guideline for the Location of Occupied Buildings in Industrial Gas Plants*, IGC Doc 187/14/E

2.4.3 BLAST EFFECTS ON BUILDINGS

Risks to physical structures will be taken into account as part of any TLUP advice. Landmark overpressure damage values are:

Overpressure (kPa)	Overpressure (mbar)	Possible damage contours
1	>10	Glass breakage
3.5	>35	Light
17	>170	Moderate
35	>350	Severe
83	>830	Total destruction

Table 14: Blast effect on buildings (extracted from Table 15)

If it is considered necessary by the CCA, the distance to some of these key contours could be plotted on a map as part of generic advice addressing consequences. Table 15 provides more detail on the damage potentially resulting from overpressure.

Overpressure (kPa)	Description of damage
0.15	Annoying noise
0.2	Occasional breaking of large windowpanes already under strain
0.3	Loud noise; sonic boom glass failure
0.7	Breakage of small windows under strain
1	Threshold for glass breakage
2	'Safe distance', probability of 0.95 of no serious damage beyond this value; some damage to house ceilings; 10% window glass broken
3	Limited minor structural damage
3.5–7	Large and small windows usually shattered; occasional damage to window frames
>3.5	Damage level for 'light damage'
5	Minor damage to house structures
8	Partial demolition of houses, made uninhabitable
7–15	Corrugated asbestos shattered. Corrugated steel or aluminium panels fastenings fail, followed by buckling; wood panel (standard housing) fastenings fail; panels blown in
10	Steel frame of clad building slightly distorted
15	Partial collapse of walls and roofs of houses
15–20	Concrete or cinderblock walls, not reinforced, shattered
>17	Damage level for 'moderate damage'
18	Lower limit of serious structural damage; 50% destruction of brickwork of houses
20	Heavy machines in industrial buildings suffered little damage; steel-frame building distorted and pulled away from foundations
20–28	Frameless, self-framing steel panel building demolished; rupture of oil storage tanks
30	Cladding of light industrial buildings ruptured
35	Wooden utility poles snapped; tall hydraulic press in building slightly damaged
35–50	Nearly complete destruction of houses
>35	Damage level for 'severe damage'
50	Loaded tank car overturned
50–55	Unreinforced brick panels, 25–35 cm thick, fail by shearing or flexure
60	Loaded train boxcars completely demolished
70	Probable total destruction of buildings; heavy machine tools moved and badly damaged
>83	Damage level for 'total destruction'

Table 15: Levels of damage from overpressure – American Institute of Chemical Engineers (1994)

While there are no generally accepted criteria for assessing the risk to the built environment (as opposed to the risk to human health), the results of an assessment using the above criteria will be an additional factor for planning authorities to consider, although that may be of less significance than the risks to people.

2.5 Toxicity

2.5.1 TOXIC EFFECTS ON PEOPLE OUT IN THE OPEN

Probit equations are used for estimating the fatal toxicity effects of dangerous substances. All probits take the form Probit = a + b ln(C^n t) where a, b and n are constants, as shown in Table 16, C is the concentration value by volume (in ppm), and t is the exposure duration (in minutes).

The exposure duration is generally taken to be equal to the release duration for vapour/gas releases, up to a maximum of 30 minutes, and also a maximum of 30 minutes for toxic exposure from evaporating liquid pools or from warehouse fires (some scenarios will be of shorter duration than this maximum).

The probit equations in Table 16 will be used in TLUP risk contour generation.

Substance	CAS #	a	b	n	Source
Ammonia	7664-41-7	-16.21	1	2	(RIVM, 2020)
Bromine	7726-95-6	-8.54	1	2	(RIVM, 2020)
Chlorine	7728-50-5	-4.81	0.5	2.75	(RIVM, 2020)
Hydrazine	302-01-2	-13.452	1.676	1	(PHAST, 2019)
Phosgene	75-44-5	-7.69	2	1	(RIVM, 2020)
Carbon monoxide	630-08-0	-7.21	1	1	(RIVM, 2020)
Methyl bromide	74-83-9	-5.75	1	1.1	(RIVM, 2020)
Methylisocyanate	624-83-9	-0.57	1	0.7	(RIVM, 2020)
Methylmercaptan	74-93-1	-16.33	2.05	0.98	(RIVM, 2020)
Nitrogen dioxide	10102-44-0	-16.06	1	3.7	(RIVM, 2020)
Nitric oxide	10102-43-9	-150.838	15.432	1	(PHAST, 2019)
Hydrogen chloride	7647-01-0	-35.62	3.69	1	(RIVM, 2020)
Hydrogen cyanide	74-90-8	-9.43	1	2.4	(RIVM, 2020)
Hydrogen fluoride	7664-39-3	-8.62	1	1.5	(RIVM, 2020)
Hydrogen sulphide	7783-06-4	-10.76	1	1.9	(RIVM, 2020)
Sulphur dioxide	7446-09-5	-16.76	1	2.4	(RIVM, 2020)

Table 16: Dangerous substances probits (concentration in ppm by volume)

Probits are available in the published literature for other dangerous substances; where there is more than one probit, the CCA will use its discretion to select an appropriate value. Quantitative risk assessments (QRAs) should justify the use of any alternative probits.

2.5.2 TOXIC EFFECTS ON PEOPLE INSIDE BUILDINGS

The risk to people indoors from a toxic vapour cloud significantly depends on the effective ventilation rate of the building they are in. Air change rates, for passively ventilated buildings, of 2.5 and 2 air changes per hour are typically assumed for D_5 and F_2 conditions. (D_5 and F_2 refer to the weather/stability sets typically used in modelling releases of dangerous substances into the atmosphere. D represents typical daytime conditions and F represents specific night-time conditions. The subscripts refer to the average wind speeds, in metres per second, associated with those atmospheric stability conditions – see also section 2.5.4)).

The impact of a toxic release on an indoor population can be assessed using the same probit equations as for outdoor exposure, but it is necessary to modify the effective concentration and duration of exposure in order to take account of gas infiltration into the building. If the modelling software does not calculate indoor concentration, the approach set out in Davies and Purdy (1986) will be followed.

2.5.3 FRACTION OF TIME SPENT INDOORS/OUTDOORS

People are assumed to be indoors 90% of the time.

2.5.4 PROBABILITY OF OCCURRENCE OF WEATHER STABILITY SETS

D_5 conditions are assumed to occur 80% of the time, with F_2 occurring for the remaining 20%.

2.5.5 TEMPERATURE PARAMETERS

Outdoor storage vessel contents are assumed to be at ambient atmospheric temperatures. Ambient temperatures vary throughout the day and the seasons. For TLUP purposes, a temperature of 15 °C is used in D_5 conditions and 10 °C for F_2 conditions.

Raw temperature data are available from Met Eireann at: (**https://www.met.ie/climate/available-data/historical-data**).

2.5.6 WIND DIRECTION PROBABILITY

The probability of a gas/vapour release (or in some cases thermal flux) being blown in any direction by the wind is taken into account, using data from the nearest weather station, typically allocating the probability over eight sectors.

2.5.7 TERRAIN

The terrain in the vicinity of the establishment, over which dispersion takes place, is carefully selected from Table 17.

#	Short description of the terrain	Roughness length (m)
1	Open water (at least 5 km)	0.0002
2	Mud flats, snow; no vegetation, no obstacles	0.005
3	Open, flat terrain; grass, a few isolated objects	0.03
4	Low vegetation; large obstacles here and there, x/h > 20	0.10
5	High vegetation; distributed large obstacles, 15 < x/h < 20	0.25
6	Park, bushes; many obstacles, x/h < 15	0.5
7	Strewn with large obstacles (suburb, wood)	1.0
8	Town centre with high-rise and low-rise buildings	3.0

Table 17: Roughness lengths (source: RIVM (2020))

By default, for general terrain without defining features, a value of 0.1 m will be used (a conservative approach).

2.5.8 TOXIC EFFECTS ON THE ENVIRONMENT

Where prevention measures fail and where local flora and fauna are more sensitive to toxic exposure than humans, a more relevant toxic endpoint (than those previously described) may be used to estimate consequences, where damage duration and resilience will be taken into account. More detail on the modelling and assessment of major accidents to the environment is contained in the HSA's *Guidance to Inspectors on the Assessment of Safety Reports under the COMAH Regulations 2015* (HSA, 2017).

2.6 Domino effects

Domino effects are effects that arise when an accident event at one establishment initiates a major accident elsewhere in the establishment, or at another establishment in the vicinity. Typical examples of where domino interactions may need to be explicitly considered include:

- Where the presence of a high-frequency short-range hazard significantly increases the likelihood of a major failure of a relatively low-frequency long-range hazard. For example, small LPG storage vessels located close to a large toxic gas storage tank.
- Where the initiating event on one site (or part of the same site) could trigger a more severe than expected event on a neighbouring site. For example, an LOC and fire involving highly flammable substances on one site could spread to involve a site storing Category 3 flammable liquids, which would normally not be considered a major fire risk (due to high flash point), but which are still very likely to be ignited and become involved in escalating the fire if the initiating event is a major fire from a nearby site.
- Where an event at one site (or part of the same site) could have unexpected indirect consequences on a neighbouring site. For example, a loss of power to control and emergency shutdown systems, or toxic vapours leading to incapacity/evacuation of vital staff controlling major hazards at a nearby site. Such unexpected indirect consequences could trigger or exacerbate a potential domino event.

In most cases, domino effects can be incorporated into the risk-based assessment by simply increasing the base case frequency for the likelihood of events on one (or both) sites.

Domino effects on road tankers have been specifically accounted for in Part 3.

Often, it is found that domino effects are not significant for LUP, as the likelihood of an event at Site A triggering a major event at Site B is an order of magnitude less than the base case likelihood of the event at Site B. Nevertheless, as a general rule of thumb, the potential for domino effects will always be considered at establishments within 500 m of each other. The paper by Salzano and Cozzani (2005) informs the approach that will be taken in the analysis of domino effects.

2.7 Unbunded pool size

Unbunded pools are given an upper limiting diameter of 100 m. Where there are physical constraints (for example, a pool can form on only one side of the bund), then the constrained pool size is modelled and the frequency is proportionally adjusted upwards.

In some cases, it could happen that a pool is constrained to a particular direction, or there may be a possibility of larger pools (or even running pools). If such effects are considered to be significant, then the analysis will be adapted appropriately.

Overtop pools will be distributed over the potential overtop locations and the frequency assigned proportionately.

If the topography of the area surrounding the bund has any special features, such as tertiary containment, then this could be accounted for by modifying the potential location of fires outside the bund, possibly reducing the extent of the LUP zones.

2.8 Surface emissive power – pool fire

The scientific literature describes a number of approaches to modelling the surface emissive power (SEP) of heat radiated outwards per unit surface area of the flame from a pool fire, in units of kW/m^2.

Maximum SEP values from the literature are:

Substance	Emax (kW/m^2)
Acetone	130
Crude oil	130
Diesel	130
Ethanol	130
Fuel oil, heavy	130
Gasoline	130
Heptane	200
Hexane	200
Hydrogen (Liquefied)	70
JP4	130
Kerosine	130
LNG/Methane	265
LNG/Methane (water)	265
LPG/Propane	250
LPG/Propane (water)	250
Methanol	70
Toluene	130
Xylene	130

Table 18: Maximum SEP values

In practice, the actual SEP is related to the pool diameter and the flame height.

For pool fires, a two-layer solid flame model is considered to better represent the effects of pool fires than the single-point model. However, there is quite a lot of variation in methods for determining flame height, effect of soot, and the effective SEP of flames.

For consistency in the area of TLUP advice, the following approach will be taken for pool fires and their off-site effects (which may **not be valid** for the assessment of near-field effects). The SEP of each flame layer of defined pool diameter will need to be adjusted from the maxima listed in Table 18, in order to account for the obscuration effects of soot (if any). The view factor(s) are also taken into account.

Flame height is to be calculated using a two-zone model (Rew *et al*, 1997) – an average surface emitted flux can be estimated based on the sum of thermal fluxes from a lower and upper layer. The emitted flux tends to decrease with increasing pool size.

For pool fire calculations, a value of 250 kW/m^2 for LPG and 265 kW/m^2 for LNG and methane gas will be used.

For jet fires, maximum SEP values will be used in all cases.

2.9 Jet fires

Jet fires are conservatively modelled as vertical releases in the standard model, with the receptor assumed to be downwind of the release.

A single-source release point is used for small tanks/pipelines, with risk points added as the length increases. The LOC frequency and dispersion modelling is spread over the number of release points.

2.10 Ignition probability

Unless otherwise indicated, the event frequencies used in the Part 3 tables include an assessment of the probability of ignition (that is, where the scenario includes the words 'fire' or 'explosion'). Therefore, a separate ignition probability assessment is not required in the standard model. Generally, ignition probabilities (see below) and conditional event probabilities (see Part 3) are based on the Dutch National Institute for Public Health and the Environment publications - RIVM (2009) and RIVM (2020), with a modification to take account of flammability categories changes introduced in the CLP Directive (footnote 22 in Part3 for full title). If the ignition probability for an accident scenario is not covered by the referenced publications then other sources or expert judgement will be used.

The Guidance on the Application of the CLP Criteria[20] (ECHA, 2017) gives this decision tree for flammable liquid classification:

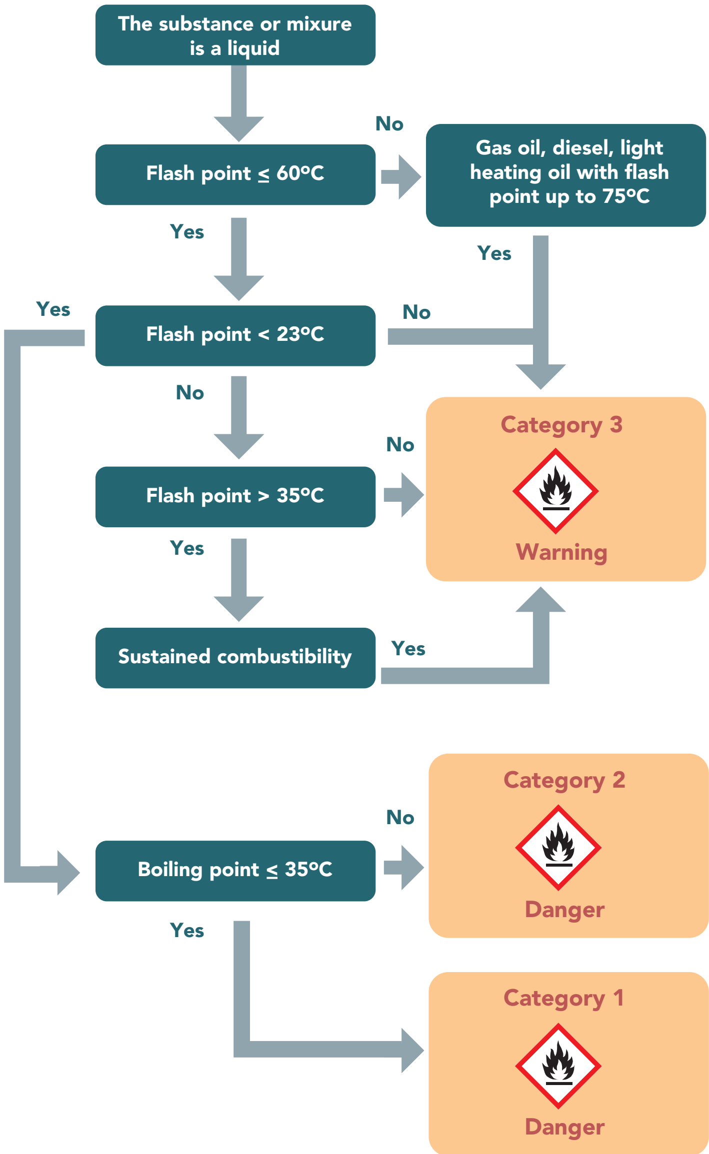


Figure 7: Amended GHS logic diagram for flammable liquids (extracted from Figure 2.3, Guidance on the Application of CLP Criteria, Version 5.0, (ECHA, 2017))

[20] *Guidance on the Application of CLP Criteria,* Version 5.0, July 2017. ECHA

Ignition categories are then assigned as follows:

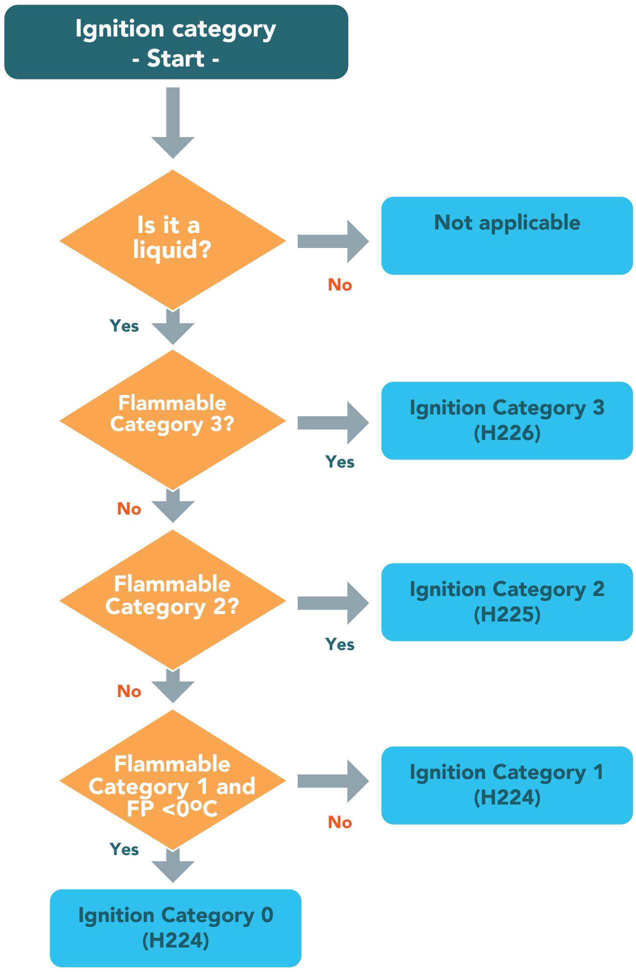


Figure 8: Assignment of Ignition Category

For the standard model, flammable liquid substances are categorised as follows:

Ignition Category	Flash point
0	FP < 0 °C, BP ≤ 35 °C
1	FP < 23 °C, BP ≤ 35 °C (excluding Category 0)
2	FP < 23 °C, BP > 35 °C
3	FP ≥ 23 °C and ≤ 60 °C*

Table 19: Ignition categories for standard model

* For the TLUP ignition probability purposes, diesel and light heating oils having a flash point between 60 °C and 75 °C (inclusive.) may be regarded as Ignition Category 3

Ignition is considered to either happen immediately or to be delayed for a short period – the modelled accident consequences reflect these two possibilities.

In the standard model, ignition probability depends on the flammability category of the dangerous substance (including flammable gases), as illustrated in Table 20 for fixed installations:

Ignition Category	Immediate ignition	Delayed ignition
0 (high reactivity)	0.7	0.3
0 (low reactivity)	0.09	0.91
Liquid Category 1	0.065	0.935
Liquid Category 2	0.01	0
Liquid Category 3	0	0

Table 20: Conditional ignition probabilities for fixed installations

Low-reactivity substances include methane, ammonia, and carbon monoxide. A substance is assigned to this category only if it is known to be of low reactivity.

Ignition probabilities for road transport unit scenarios are treated as follows:

Flammability	Immediate ignition	Delayed ignition
0, instantaneous	0.4	0.6
0, continuous	0.1	0.9
Liquid Category 1	0.065	0.935
Liquid Category 2	0.01	0
Liquid Category 3	0	0

Table 21: Conditional ignition probabilities for road transport unit scenarios

Note that in the above tables, for ignition categories 0 and 1, the total ignition probability is 1.

For gas (LPG/LNG) at jetties, the following are used:

Release type	Immediate ignition	Delayed ignition
Continuous, large	0.7	0.3
Continuous, small	0.5	0.5

Table 22: Conditional ignition probability for gas (LPG or LNG) at a jetty

Conditional delayed ignition probability is split into 0.4 for a VCE and 0.6 for a flash fire in the standard model.

2.11 BLEVEs

Boiling liquid expanding vapour explosions (BLEVEs) typically relate to flammable gases under excess pressure as a result of an externally applied heating source. If the containment fails catastrophically, an explosion overpressure and a fireball results.

As a result of the dominating effects of the fireball, it is used exclusively in determining BLEVE effects for TLUP. In keeping with the *Policy & Approach of the Health & Safety Authority to COMAH Risk-based Land-use Planning (19 March 2010)* an SEP of 275 kW/m² for LPG is used in the standard model. No account is taken of fireball lift-off in the standard model calculations.

2.12 More complex establishments

For complex sites, the installation-specific approaches, as outlined in Part 3, can be combined. For example, a pharmaceutical manufacturing/processing site may have a chemical warehouse, bulk flammable storage, toxic gas cylinders, and a synthesis plant and therefore each of these may have to be accounted for in the development of generic advice.

2.13 Limitations of a risk-based approach

While the risk-based approaches detailed in Part 3 are not as comprehensive as fully quantified risk assessments (QRAs), they are judged to fulfil the principles of robustness, consistency and transparency required for a TLUP advice system.

A risk-based approach inevitably involves assumptions concerning the frequency of accidents. However, this is preferable to the hazard-based approach, where it is implicitly assumed that the particular event chosen has a likelihood that is sufficient to be a cause for concern, but not so high as to make it unacceptable.

As the TLUP advice methodology focuses on off-site risk, it may underestimate the risk from lesser but more frequent events close to the source.

The field of risk assessment continues to develop, both in the understanding of the major accident events themselves and the criteria that should be used to assess such accidents. This Guidance cannot be expected to cover every situation. It is intended to provide the basis for robust assessment, but there will, at times, be a need to refine particular aspects and to generally adapt to technical progress or to take account of particular local conditions and the CCA reserves this right for itself.

Caution is advised in attempting to use the approach described in this document for purposes other than TLUP advice because:

- The objective of the methodology relates to TLUP advice, which is external to the establishment and is future oriented: the assessment methods presented here are not sufficiently detailed to address risk to on-site populations and should not be used for that purpose.
- The system is designed to be used in its totality, and parts should not be mixed and matched with other systems, or be used out of this TLUP context, without clear and sufficient justification.

Part 3: Method for specific sectors

3.1 LPG (Liquefied Petroleum Gas) installations

3.1.1 FIXED STORAGE INSTALLATIONS

For fixed LPG installations, three LOC accident scenarios are modelled:

- an instantaneous loss of an entire vessel contents, resulting in a BLEVE, a VCE and a flash fire;
- loss of the entire vessel contents over 10 minutes, resulting in VCE, flash fire and jet fire;
- loss (over 30 minutes) through a 10 mm hole (or hole sized to largest connection) – VCE, flash fire, and jet fire.

The frequencies for each of these events (which include the ignition probabilities) are shown in Table 23.

LOC scenario	Frequency (yr^{-1})	Consequence	Frequency	Event #
Instantaneous failure	5×10^{-7}	BLEVE/Fireball	3.5×10^{-7}	001
		VCE	6×10^{-8}	002
		Flash fire	9×10^{-8}	003
Continuous leak over 10 minutes	5×10^{-7}	Jet fire	3.5×10^{-7}	004
		VCE	6×10^{-8}	005
		Flash fire	9×10^{-8}	006
10 mm pipe leak over 30 minutes	1×10^{-5}	Jet fire	7×10^{-6}	007
		VCE	1.2×10^{-6}	008
		Flash fire	1.8×10^{-6}	009

Table 23: Event frequencies for a single fixed LPG vessel

Events numbered 007, 008 and 009 have lesser consequences than the other events, but are more probable. It may be possible to omit them for sites where the inventory is distant from the establishment boundary.

3.1.2 ROAD TRANSPORT UNITS

For road transport units present in an establishment, two LOC events are considered:

- Instantaneous loss of entire contents, leading to a BLEVE/Fireball, VCE, and flash fire;
- loss of entire contents through largest connection, resulting in a VCE, flash fire, and jet fire.

The frequencies for each of these events (which include ignition probabilities) are shown in Table 24.

LOC scenario	Frequency (yr^{-1})	Consequence	Frequency	Event #
Instantaneous failure	5×10^{-7}	Fireball	2×10^{-7}	010
		VCE	1.2×10^{-7}	011
		Flash fire	1.8×10^{-7}	012
Loss of entire contents through largest connection	5×10^{-7}	Jet fire	5×10^{-8}	013
		VCE	1.8×10^{-7}	014
		Flash fire	2.7×10^{-7}	015

Table 24: Event frequencies for road transport units (per active unit on-site per year)

The above frequencies should be adjusted for the proportion of the year that the laden road transport unit is present.

Some transport unit risks are also specifically associated with the on-site loading/unloading of LPG.

Table 25 lists these LOC scenarios.

LOC scenario	Arm – Frequency (hr^{-1}) – Hose		Event #
Rupture of loading/unloading arm/hose	3×10^{-8}	4×10^{-6}	016
Leak of loading/unloading arm/hose 10% of diameter	3×10^{-7}	4×10^{-5}	017

Table 25: LOCs for loading/unloading LPG operations

Such leaks should be of short duration, due to blocking measures, and could be neglected on sites where the loading location is distant from the boundary. Additionally, the following domino effect should be considered for the duration of the loading operation:

LOC scenario	Frequency (hr^{-1})	Event #
BLEVE (hot)	5.8×10^{-10}	018

Table 26: BLEVE frequency for tanker loading operations

The LOCs in Table 25 and Table 26 relate to the hours engaged in actual loading/unloading activities.

3.1.3 JETTY

If a jetty charging/discharging LPG is within or adjacent to the establishment, a major accident during loading/unloading operations will be taken into account. The scenarios modelled are for releases of 180 m^3 and 90 m^3 of LPG over 30 minutes.

LOC scenario	Frequency (yr^{-1})	Consequence	Frequency	Event #
Continuous leak of 180 m^3 over 30 minutes	1.2×10^{-4}	Jet fire	8.4×10^{-5}	019
		VCE	1.44×10^{-5}	020
		Flash fire	2.16×10^{-5}	021
Continuous leak of 90 m^3 over 30 minutes	2.5×10^{-2}	Jet fire	1.25×10^{-2}	022
		VCE	5×10^{-3}	023
		Flash fire	7.5×10^{-3}	024

Table 27: Event frequencies for an LPG jetty

The LOC frequency figures in Table 27 are to be multiplied by f_o.[21].

The explosion volumes to be modelled in the multi-energy method are the stoichiometric volumes generated by these released gas volumes – 20% at strength 7 and 80% at strength 2.

3.1.4 BURIED AND FULLY MOUNDED VESSELS

It is implicitly assumed in these figures that an establishment meets all the good practice standards required for an LPG installation (for example, by having a water deluge system or protective vessel coating) and there may be few, if any, cost-effective additional technical measures that will significantly reduce the extent of LUP risk-based zones. One possible risk reduction measure is to fully mound (or bury) the LPG vessels. In such circumstances, the likelihood of a BLEVE from an instantaneous failure is significantly reduced. This is reflected in Table 28.

LOC scenario	Frequency (yr^{-1})	Consequence	Frequency	Event #
Instantaneous failure	5×10^{-7}	Fireball	1.05×10^{-7}	025
		Flash fire	9×10^{-8}	026
		VCE	6×10^{-8}	027
Continuous leak over 10 minutes	5×10^{-7}	Jet fire	3.5×10^{-7}	028
		VCE	6×10^{-8}	029
		Flash fire	9×10^{-8}	030
10 mm pipe leak over 30 minutes	1×10^{-5}	Jet fire	7×10^{-6}	031
		VCE	1.2×10^{-6}	032
		Flash fire	1.8×10^{-6}	033

Table 28: Scenarios for mounded/buried LPG vessels

Events # 031, 032 and 033 have lesser consequences than the other events, but are more probable. It may be possible to omit them for sites where the inventory is distant from the establishment boundary.

3.1.5 UNCERTAINTIES IN THE LPG RISK-BASED APPROACH

The risk analysis method as described is somewhat simplistic and neglects smaller but more probable events, such as smaller vessel leaks and pipe leaks. Because the risk values generated are being used for off-site control purposes, this is considered to be a reasonable approach (and is also a reason why this methodology is not suitable for detailed on-site risk analysis).

[21] $f_o = N*T*t*6.7 \times 10^{-11}$, where T is the total number of ships on the transport route annually, t is the average unloading/loading duration (hours) and N is the number of transhipments per year.

3.2 LNG (liquefied natural gas) installations

3.2.1 FIXED INSTALLATIONS

LNG may be stored on its own or in association with LPG (see Section 3.1). Although LNG can be stored as a liquid (-161 °C) at just above atmospheric pressure, it is more likely to be stored under significant pressure (up to 8–10 bar). The modelling scenarios are therefore similar to those for LPG, but greater allowance is made for pool fires because they are more probable when an LOC of cryogenic methane occurs.

This section does not address jetty operations, floating storage units (FSUs), or floating storage and regasification units (FSRUs).

For fixed LNG installations (including transport containers manufactured according to the specifications outlined by the International Organization for Standardization (ISO containers) for the duration they are removed from a road transport cab), the following scenarios are modelled:

LOC scenario	Frequency (yr^{-1})	Consequence	Frequency	Event #
Instantaneous failure	5×10^{-7}	BLEVE/Fireball	4.5×10^{-8}	034
		VCE	9.1×10^{-8}	035
		Flash fire	1.37×10^{-7}	036
		Pool fire	2.28×10^{-7}	037
Continuous leak over 10 minutes (total inventory)	5×10^{-7}	Jet fire	4.5×10^{-8}	038
		VCE	9.1×10^{-8}	039
		Flash fire	1.37×10^{-7}	040
		Pool fire	2.28×10^{-7}	041
10 mm pipe leak over 30 minutes	1×10^{-5}	Jet fire	9×10^{-7}	042
		VCE	1.82×10^{-6}	043
		Flash fire	2.73×10^{-6}	044
		Pool fire	4.55×10^{-6}	045

Table 29: Event frequencies for fixed LNG installations (per storage unit per year)

For TLUP purposes, the VCE and flash fire events are located at the source.

Consideration must be given to any associated regasification units, if present, which are treated as heat exchangers. Table 30 lists the scenario and frequency.

LOC scenario	Frequency (yr^{-1})	Event #
Rupture of 10 pipes at the same time	1×10^{-6}	046

Table 30: Regasification unit scenario

3.2.2 ROAD TRANSPORT UNITS

For ISO road transport units associated with delivery and transport of LNG, the scenarios are:

LOC scenario	Frequency (yr^{-1})	Consequence	Frequency	Event #
Instantaneous failure	5×10^{-7}	Fireball	2.00×10^{-7}	047
		VCE	6.00×10^{-8}	048
		Flash fire	9.00×10^{-8}	049
		Pool fire	1.50×10^{-7}	050
Continuous leak over 10 minutes	5×10^{-7}	Fireball	5.00×10^{-8}	051
		VCE	9.00×10^{-8}	052
		Flash fire	1.35×10^{-7}	053
		Pool fire	2.25×10^{-7}	054

Table 31: Event frequencies for road transport units (per active unit on-site)

The frequencies should be adjusted for the proportion of the year that the laden transport unit is present.

Road transport unit risks might also be specifically associated with the on-site loading/unloading of LNG.

Table 32 lists the relevant LOCs.

LOC scenario	Arm – Frequency (hr^{-1}) – Hose		Event #
Rupture of loading/unloading arm/hose	3×10^{-8}	4×10^{-6}	055
Leak of loading/unloading arm/hose 10% Diameter	3×10^{-7}	4×10^{-5}	056

Table 32: LOCs for loading/unloading LNG operations

Additionally, the following domino effect must also be taken into account for loading/unloading activities:

LOC scenario	Frequency (hr^{-1})	Event #
Pool Fire	5.8×10^{-9}	057

Table 33: Pool Fire frequency for road transport unit loading operations

The LOCs in both tables relate to the hours engaged in actual loading/unloading activities.

3.2.3 UNCERTAINTIES IN LNG RISK-BASED APPROACH

The risk analysis method in Section 3.2 is somewhat simplistic and it neglects smaller but more probable events such as smaller vessel leaks and pipe leaks. Because the risk values generated are being used for off-site control purposes, this is considered to be a reasonable approach.

3.3 Renewable natural gas (RNG) installations

This includes the activity of generating methane (biomethane) from biological digesters.

Digesters are considered to have failure frequencies equivalent to atmospheric storage vessels, since the pressure load is much less than 0.5 bar above atmospheric pressure.

Some sites compress the gas into small pressurised containers for transport off-site and these are also included in the scenarios used for the development of generic TLUP contours.

If LPG or LNG are present on a site, then the methodology in the Section 3.1 and Section 3.2 must also be applied.

3.3.1 LOC SCENARIOS

The following scenarios are modelled for each digester:

LOC scenario	Frequency (yr^{-1})	Consequence	Frequency	Event #
Instantaneous failure	5×10^{-6}	Fireball*	4.5×10^{-7}	058
		VCE	1.64×10^{-6}	059
		Flash fire	2.46×10^{-6}	060
		None	4.55×10^{-7}	061
Continuous leak over 10 minutes	5×10^{-6}	Jet fire	4.5×10^{-7}	062
		VCE	1.64×10^{-6}	063
		Flash fire	2.46×10^{-6}	064
		Pool fire	4.55×10^{-7}	065

Table 34: Scenarios for bulk biomethane storage

*For the instantaneous failure, the contents of the digester are assumed to be in a fireball centred on the digester – as the pressure drops from the initial jet fire, the flame propagates back to the digester.

The pressure vessels containing the processed gas are treated as follows:

LOC scenario	Frequency (yr^{-1})	Event #
Instantaneous release	5×10^{-7}	066
Release over 10 minutes	5×10^{-7}	067
Release through 10 mm pipe	1×10^{-5}	068

Table 35: Scenarios for pressurised drums of processed biogas

3.4 Hydrogen installations

This section covers gaseous hydrogen in any type of pressurised vessel, it does not address jetty operations, or hydrogen stored as a liquid.

Hydrogen is typically stored as a compressed gas in pressurised vessels such as cylinders or tube trailers at pressures between 350 and 700 barg. Due to its small molecular size, it also has the potential to diffuse through containment structures. It has a very wide flammability range (4–75%) and extremely low minimum ignition energy.

Hydrogen is very readily ignitable (even by static spark from a person or by phenomenon such as shockwave auto ignition, where high pressure releases can self-ignite with no obvious sources of ignition) and can ignite at a wide range of concentrations and therefore, an ignition probability of 100% is considered to be a reasonable assumption for the purposes of land use planning relating to major accidental releases.

A particular focus should be given to vapour cloud explosion (VCE) consequences for hydrogen as these are expected to be more severe than other ignited events with their effects much further reaching. Explosions are also proven to be much more prevalent in hydrogen incident recordings than other types of events in comparison to conventional fuel releases.

Due to the emerging nature of the industrial scale generation, storage and use of hydrogen, it is recommended to use equipment failure frequencies described in this section, until a robust dataset specific for hydrogen is developed.

3.4.1 Fixed Installations

For fixed hydrogen installations located outdoors (including, but not limited to, bulk storage vessels) the following scenarios should be modelled:

LOC Scenario	Frequency (yr^{-1})	Consequence	Frequency (yr^{-1})	Event#
Instantaneous failure	5×10^{-6}	VCE/Fireball	5×10^{-6}	069
Continuous leak over 10 minutes (total inventory)	1×10^{-5}	Jet Fire VCE Flash Fire	7×10^{-6} 1.2×10^{-6} 1.8×10^{-6}	070 071 072
10 mm pipe leak over 10 minutes	5×10^{-4}	Jet Fire VCE Flash Fire	3.5×10^{-4} 6×10^{-5} 9×10^{-5}	073 074 075

Table 36: Event Frequencies for Outdoors Bulk Hydrogen Storage (per Vessel)

As hydrogen is more likely to ignite immediately, in the case of an instantaneous failure, the worst case consequence should be taken from either the fireball or VCE event.

The consequence frequencies in Table 36 for continuous leaks and pipe leaks are based upon a split of 70:30 between immediate and delayed ignition from fixed installations (given that hydrogen is best described as an Ignition 0 (high reactivity) gas), with a 70% immediate ignition probability of a jet fire and a 40% probability of a VCE occurring instead of a flash fire scenario (RIVM, 2020 guidance).

For fixed hydrogen installations located indoors (including equipment such as electrolysers, heat exchangers, and compressors) the following scenarios should be modelled:

LOC Scenario	Frequency (yr^{-1})	Consequence	Frequency (yr^{-1})	Event#
Instantaneous failure	5×10^{-6}	VCE/Fireball	5×10^{-6}	076
Continuous leak over 10 minutes (total inventory)	1×10^{-5}	Jet Fire VCE	7×10^{-6} 3×10^{-6}	077 078
10 mm pipe leak over 10 minutes	5×10^{-4}	Jet Fire VCE	3.5×10^{-4} 1.5×10^{-4}	079 080

Table 37: Event Frequencies for Indoor Hydrogen Equipment Releases (per Vessel / Equipment)

As hydrogen is more likely to ignite immediately, in the case of an indoor instantaneous failure, the worst-case consequence should be taken from either the fireball or VCE event.

The consequence frequencies in Table 37 are again based upon a split of 70:30 between immediate and delayed ignition from fixed installations (given that hydrogen is best described as an Ignition 0 (high reactivity) gas) and 100% probability of VCE occurring instead of a flash fire scenario (which is considered reasonable given the large explosivity range of hydrogen).

It is noted that the frequency for the 10 mm pipe leak over 10 minutes includes allowance for failures from all associated pipework equipment and fittings, and hence it may be conservative for a simple installation.

3.4.2 Road Transport Units

For compressed gaseous hydrogen stored or transported in cylinder arrays by road transport units (RTUs), the scenarios are:

LOC Scenario	Frequency (yr^{-1})	Consequence	Frequency (yr^{-1})	Event#
Instantaneous failure	N x (5×10^{-7})	VCE/Fireball	N x (5×10^{-7})	081
Loss of entire contents (complete cylinder array) through largest connection	N x (5×10^{-7})	Jet Fire Flash Fire VCE	N x (2×10^{-7}) N x (1.8×10^{-7}) N x (1.2×10^{-7})	082 083 084

Table 38: Event Frequencies for Road Transport Units On-Site (per Pressurised Cylinder Array with 'N' Cylinders)

As hydrogen is more likely to ignite immediately, in the case of an instantaneous cylinder failure, the worst case consequence should be taken from either the fireball or VCE event.

The frequencies should be adjusted for the proportion of the year that the laden RTU is present. The consequence frequencies given in Table 38 are also applicable for hydrogen storage cylinder arrays which are not stored on RTUs.

The consequence frequencies in Table 38 for continuous releases are based upon a 60% probability of delayed ignition (in line with "Flammability 0, instantaneous" event for RTUs in Table 21) and a 40% probability of VCE occurring instead of a flash fire scenario (RIVM, 2020 guidance).

In addition to the risks associated with the presence of an RTU, as described above, there will also be risks associated with the on-site loading / unloading of hydrogen as detailed below:

LOC Scenario	Frequency (hr^{-1})		Event#
	Arm	Hose	
Rupture of loading / unloading arm/hose	3×10^{-8}	4×10^{-6}	085
Leak of loading / unloading arm/hose (10% diameter)	3×10^{-7}	4×10^{-5}	086

Table 39: Event Frequencies for Hydrogen Loading / Unloading Operations

3.4.3 Pipelines

LOC scenarios for hydrogen pipelines are considered to be analogous to that of natural gas (NG) due to the similarities in the way the fluids are carried in the pipeline and the likely causes of failure which could lead to pipeline LOC.

Refer to Table 40 and Table 41 covering LOC scenarios for over ground and underground NG pipelines within an establishment respectively.

However, consequence frequencies should assume a 100% ignition probability, 30% probability of delayed ignition, and a 40% probability of VCE occurring instead of a flash fire scenario as per Table 36 concerning outdoor releases from bulk hydrogen storage.

3.4.4 Hydrogen Explosion Modelling Guidance

Given the ignitability of hydrogen (especially if it is released at high pressures), it is recommended to assume that all releases would be ignited leading to either an immediate or delayed event.

The likelihood of a significant detonation (with blast overpressures exceeding 10 bar in the near field) is much greater for hydrogen than for methane or LPG. Therefore, it is recommended to model a VCE of ignition strength 7 (with respect to the TNO multi-energy method (Van den Berg, 1985)) for 40% of the total flammable cloud volume (or using a site specific estimate of volume) in an outdoors environment (i.e. representative of the outdoor scenarios listed in Table 36, Table 38, and Table 39).

The magnitude of an overpressure generated inside an enclosed space (i.e. representative of the scenarios listed in Table 37) should be based upon the entire volume of the enclosure filled at a flammable (stoichiometric) concentration with ignition strength of 7. There is potential for even small releases from hydrogen systems to fill enclosures to flammable levels especially given the high pressure at which the systems are maintained giving high release rates and hydrogen's large flammability range.

3.4.5 Uncertainties in the Hydrogen risk based approach

For TLUP purposes, the VCE and fireball events are located at the source. In addition, VCE consequences are expected to dominate other potential scenarios (such as jet fires or flash fires).

The risk analysis method as described in this section is somewhat simplistic and neglects smaller but more probable events, such as smaller vessel leaks and pipe leaks. Because the risk values generated are being used for off-site control purposes, this is considered to be a reasonable approach and is also a reason why this methodology is not suitable for detailed on-site risk analysis.

3.5 Natural gas pipelines within an establishment

This section describes the approach to be taken for establishments where there is a significant major accident risk associated with releases from on-site natural gas (NG) pipelines.

3.5.1 LOC SCENARIOS AND FREQUENCIES

Table 40 gives the LOC frequencies associated with pipework that will be used to develop standard generic TLUP advice.

	Frequency (m^{-1} yr^{-1})			Event #
LOC scenario	D < 75 mm	75 ≤ D ≥ 150 mm	D>150 mm	
Pipeline rupture	1×10^{-6}	3×10^{-7}	1×10^{-7}	087
Pipeline leak of 0.1D (max 50mm)	5×10^{-6}	2×10^{-6}	5×10^{-7}	088

Table 40: LOCs for overground pipes of varying diameters

For underground pipes, an order of magnitude reduction is applied in the standard model and the following values are used:

	Frequency (m^{-1} yr^{-1})			Event #
LOC scenario	D < 75 mm	75 ≤ D ≥ 150 mm	D>150 mm	
Pipeline rupture	1×10^{-7}	3×10^{-8}	1×10^{-8}	089
Pipeline leak of 0.1D (max 50mm)	5×10^{-7}	2×10^{-7}	5×10^{-8}	090

Table 41: LOCs for underground pipes of varying diameters

The concern for TLUP purposes is primarily with the effects on humans, but environmental effects should not be disregarded. Modelling will use typical atmospheric stability conditions (D_5/F_2).

NG pipeline ruptures and leaks are assumed to be continuous rather than instantaneous. The consequences associated with the LOCs are jet fires, flash fires, and VCEs. Because methane is categorised as being of low reactivity (Yellow Book), the immediate ignition probability is low; therefore, a jet fire is a less likely event than might be expected. The conditional probabilities for a flammable gas release from a pipeline (based on the event tree in Figure 4 of RIVM 2020) are shown in Table 42.

Event	Conditional probability
Fireball/Jet fire	0.1
Flash fire	0.9 × 0.6 = 0.36
VCE	0.9 × 0.4 = 0.54

Table 42: Conditional probabilities for fire and explosion from gas release

3.6 Flammable liquid storage installations

The non-environmental specific scenarios considered are pool fire, VCE, and flash fire. If the flammable substance is also toxic, then toxic effects on people must also be considered, as well as relevant environmental scenarios.

According to the Classification, Labelling and Packaging Regulation (CLP)[22] flammable liquids consist of three categories with associated Hazard (H) phrases. These are set out in Table 43.

Category	Criteria	H #
1	Flash point < 23 °C and initial boiling point ≤ 35 °C	224
2	Flash point < 23 °C and initial boiling point > 35 °C	225
3	Flash point ≥ 23 °C and ≤ 60 °C [(1)]	226

(1) For the purpose of this Regulation gas oils, diesel and light heating oils having a flash point between ≥ 55 °C and ≤ 75 °C may be regarded as Category 3.

Table 43: CLP classification of flammable substances

Ignition probabilities were given in Section 2.10 of Part 2, for flammable liquids at ambient temperature. Figure 8 and Tables 19, 20 and 21 should be referred to for assignment of Ignition Category.

3.6.1 IGNITION CATEGORY 0 SUBSTANCES AND MIXTURES

There are very few flammable liquids that fall into Ignition Category 0, but crude oil, gasoline, pentane, and diethyl ether are examples of substances that will probably fall into this category (relevant Safety Data Sheet (SDS) to be consulted for physical data).

Operators are expected to comply with good practice and to have implemented all of the recommendations in the final report into the Buncefield accident.[23] The consequences of tank overfilling are expected to be within

[22] The Classification, Labelling and Packaging Regulation on classification, labelling and packaging of substances and mixtures amending and repealing Directives 67/548/EEC and 1999/45/EC, and amending Regulation (EC) No 1907/2006(EC) No 1272/2008.
[23] *The Buncefield Incident 11 December 200 The final report of the Major Incident Investigation Board* , HSE Books(2007)

the envelope of consequences described in Table 44, but could be added to by the CCA, if considered necessary.

Some simplification has been made in the number of LOC scenarios, with early and late pool fires being consolidated into a single event, for example. It may be possible to ignore LOCs with limited off-site impact on sites with many hazard sources. However, such events should be considered when assessing significant modifications and, for TLUP, where the (initial) CD does not extend off-site.

For a single containment atmospheric storage tank storing Ignition Category 0 substance/mixture, the LOC event frequencies are:

LOC scenario	Frequency (yr^{-1})	Consequence	Frequency	Event #
Instantaneous failure	5×10^{-6}	Pool fire	9.96×10^{-7}	091
		VCE	1.82×10^{-6}	092
		Flash fire	5.46×10^{-7}	093
		None/Toxic	1.64×10^{-6}	094
Failure over 10 minutes	5×10^{-6}	Pool fire	9.96×10^{-7}	095
		VCE	1.82×10^{-6}	096
		Flash fire	5.46×10^{-7}	097
		None/Toxic	1.64×10^{-6}	098
10 mm pipe leak over 30 minutes	1×10^{-4}	Pool fire	1.99×10^{-5}	099
		VCE	3.64×10^{-5}	100
		Flash fire	1.09×10^{-5}	101
		None/Toxic	3.28×10^{-5}	102

Table 44: Event frequencies for Ignition Category 0 flammable liquids

The toxic events in Table 44 are only relevant if the substance carries a H300/310/330/370 classification.

Instantaneous tank failure will most likely lead to bund overtopping, which means that the first scenarios in Table 44 occur both inside and outside the bund. The overtopping percentage is based on actual site conditions, with 50% assumed by default. The overtop pool size is based on site conditions and modelling parameters, but the pool diameter modelled is never greater than 100m.

LOC scenario	Frequency (yr^{-1})	Consequence	Frequency	Event #
Instantaneous failure – overtop	5×10^{-6}	Pool fire	9.96×10^{-7}	103
		VCE	1.82×10^{-6}	104
		Flash fire	5.46×10^{-7}	105
		None/Toxic	1.64×10^{-6}	106

Table 45: Event frequencies for overtop scenarios, Ignition Category 0 flammable liquids

The magnitude of the overpressure generated by the VCE is that arising from a cloud volume based on a stoichiometric burning ratio of the vapourised liquid, by default with an ignition strength of 7 for 20% of the volume and a combustion energy of 3.5 MJ/m³, using the TNO multi-energy method (Van den Berg, 1985).

3.6.2 IGNITION CATEGORY 1 SUBSTANCES AND MIXTURES

The majority of CLP 1 flammable liquids fall into Ignition Category 1. Operators are expected to comply with good practice and to have implemented all the recommendations in the final report into the Buncefield accident. The consequences of tank overfilling are expected to be within the envelope of consequences described in Table 46, but could be added to by the CCA, if considered necessary.

The scenarios to be modelled are:

LOC scenario	Frequency (yr^{-1})	Consequence	Frequency	Event #
Instantaneous failure	5×10^{-6}	Pool fire	8.86×10^{-7}	107
		VCE	1.87×10^{-6}	108
		Flash fire	5.61×10^{-7}	109
		None/Toxic/MATTE	1.68×10^{-6}	110
Failure over 10 minutes	5×10^{-6}	Pool fire	8.86×10^{-7}	111
		VCE	1.87×10^{-6}	112
		Flash fire	5.61×10^{-7}	113
		None/Toxic/MATTE	1.68×10^{-6}	114
10 mm pipe leak over 30 minutes	1×10^{-4}	Pool fire	1.77×10^{-5}	115
		VCE	3.74×10^{-5}	116
		Flash fire	1.12×10^{-5}	117
		None/Toxic/MATTE	3.37×10^{-5}	118

Table 46: Event frequencies for Ignition Category 1 flammable liquids

The magnitude of the overpressure generated by a VCE in Table 46 is that arising from a cloud volume based on a stoichiometric burning volume of the vapourised liquid, by default with ignition strength of 7 for 20% of the volume, assumed to be confined, and a combustion energy of 3.5 MJ/m³, using the TNO multi-energy method (Van den Berg, 1985).

Instantaneous tank failure will most likely lead to bund overtopping, which means that the first scenarios occur both inside and outside the bund. The overtopping percentage is based on actual site conditions, with 50% assumed by default. The overtop pool size is based on site conditions and modelling parameters, but the pool diameter modelled is never greater than 100 m. The overtop scenarios are listed in Table 47.

LOC scenario	Frequency (yr^{-1})	Consequence	Frequency	Event #
Instantaneous failure – overtop	5×10^{-6}	Pool fire	8.86×10^{-7}	119
		VCE	1.87×10^{-6}	120
		Flash fire	5.61×10^{-7}	121
		None/Toxic/MATTE	1.68×10^{-6}	122

Table 47: Event frequencies for overtop scenarios, Ignition Category 1 flammable liquids

3.6.3 IGNITION CATEGORY 2 SUBSTANCES AND MIXTURES

Ignition probabilities for Category 2 substances are very low. Pool fire is the only scenario of relevance for this category, provided it is not in the same bund as CLP category 1 substances. For TLUP purposes, accidents to the environment must also be considered. Other fire and explosion events are not considered for Category 2 substances unless they are co-located with Category 1, in which case they could be modelled as Category 1.

Many flammable liquids have flash points of less than 23 °C and a boiling point above 35 °C.

Table 48 lists the relevant scenarios and events.

LOC scenario	Frequency (yr-1)	Consequence	Frequency	Event #
Instantaneous failure	5×10^{-6}	Pool fire	5×10^{-8}	123
		None/Toxic/MATTE	4.95×10^{-6}	124
Failure over 10 minutes	5×10^{-6}	Pool fire	5×10^{-8}	125
		None/Toxic/MATTE	4.95×10^{-6}	126
10 mm pipe leak over 30 minutes	1×10^{-4}	Pool fire	1×10^{-6}	127
		None/Toxic/MATTE	9.9×10^{-5}	128

Table 48: Event frequencies for Ignition Category 2 flammable liquids

An overtop pool fire is also modelled at a frequency of 5×10^{-8} per tank.

3.6.4 IGNITION CATEGORY 3 SUBSTANCES AND MIXTURES

Ignition probabilities for Category 3 substances are zero. Fire and explosion events are not considered for Category 3 substances, unless they are co-located in the same bund as Category 1 or Category 2 substances, in which case they could be modelled as Category 1 or Category 2 substances.

Failure to retain spilled material on-site means that prevention of ignition will no longer be within the control of the operator of an establishment and therefore the approach outlined above, in relation to ignition probability, does not apply and pool fires do have to be modelled. Operators generally do not have control of areas outside the establishment, so an overtop pool running off-site means that control of ignition sources, physical effects, and effects on third parties require consideration and a pool fire and its consequences will have to be modelled.

Clearly, a MATTE is a major consideration in such circumstances. As described in Section 1.8, a preventive approach is preferred regarding major accidents to the environment.

Provided that there are no other flammable substances on the site, or in the vicinity, close enough to initiate a major accident and it is clear that any credible spill will remain on-site, the probability of a Category 3 fire will not be considered credible.

3.6.5 ROAD TRANSPORT UNITS IN AN ESTABLISHMENT

Road transport units are taken into account in the scenarios listed in Table 49 and Table 50.

For Ignition Category 0:

LOC scenario	Frequency (yr-1)	Consequence	Frequency	Event #
Instantaneous failure	1×10^{-5}	Pool fire	4.36×10^{-6}	129
		VCE	2.4×10^{-6}	130
		Flash fire	2.88×10^{-6}	131
		None/Toxic/MATTE	3.6×10^{-7}	132
Failure over 10 minutes	5×10^{-7}	Pool fire	7.7×10^{-8}	133
		VCE	1.8×10^{-7}	134
		Flash fire	2.16×10^{-7}	135
		None/Toxic/MATTE	2.7×10^{-8}	136

Table 49: Event frequencies for Ignition Category 0 liquid transport units, per unit per year, proportionally

For Ignition Category 1:

LOC scenario	Frequency (yr^{-1})	Consequence	Frequency	Event #
Instantaneous failure	1×10^{-5}	Pool fire	1.21×10^{-6}	137
		VCE	3.74×10^{-6}	138
		Flash fire	4.49×10^{-6}	139
		None/Toxic/MATTE	5.61×10^{-7}	140
Leak from largest connection	5×10^{-7}	Pool fire	6.06×10^{-8}	141
		VCE	1.87×10^{-7}	142
		Flash fire	2.24×10^{-7}	143
		None/Toxic/MATTE	2.81×10^{-8}	144

Table 50: Event frequencies for Ignition Category 1 liquid transport units, per unit per year, proportionally

For Ignition Category 2, only direct ignition scenarios are considered; therefore, only pool fire, toxic and MATTE risks are considered, as shown in Table 51.

LOC scenario	Frequency (yr^{-1})	Consequence	Frequency	Event #
Instantaneous failure	1×10^{-5}	Pool fire	1×10^{-7}	145
		None/Toxic/MATTE	9.9×10^{-6}	146
Leak largest connection	5×10^{-7}	Pool fire	5×10^{-9}	147
		None/Toxic/MATTE	4.95×10^{-8}	148

Table 51: Event frequencies for Ignition Category 2 flammable liquid road transport units

The frequencies should be adjusted for the proportion of the year that the transport unit is present.

The following scenarios are taken into account for all road tanker loading/unloading operations, as shown in Figure 52.

LOC scenario	Arm – Frequency (hr^{-1}) – Hose		Event #
Rupture of loading/ unloading arm/hose	3×10^{-8}	4×10^{-6}	149
Leak of loading/ unloading arm/hose 10%	3×10^{-7}	4×10^{-5}	150

Table 52: LOCs for loading/unloading operations, road tanker

The figures in Table 52 are for the LOC scenario only; therefore, the ignition probability then has to be factored in. Additionally, failure due to a road tanker domino effect has to be included, as in Table 53.

LOC scenario	Frequency (hr^{-1})	Event #
Pool fire	5.8×10^{-9}	151

Table 53: LOC related to domino effect for road tanker

Modelled pool fire diameters for road tankers should never exceed 100 m.

3.6.6 KEY TECHNICAL MEASURES FOR NEW INSTALLATIONS

It is anticipated that new flammable liquid storage installations will install double-skin containment tanks or full containment tanks. Double-skinned tanks will likely represent the lowest risk and eliminate MATTEs from consideration and therefore comfortably fit within the 'all necessary measures' that COMAH operators must take. If operators choose not to take this route to compliance, they must demonstrate, through cost-benefit analysis, that all necessary measures have been achieved by alternative means.

Full containment atmospheric storage tanks are assigned a single scenario (release of entire contents) at a frequency of 1×10^{-8} per year.

LOCs scenarios and frequencies for double containment tanks are given in Table 54.

LOC scenario	Frequency (yr^{-1})	Consequence	Event #
Instantaneous failure of primary container and outer shell	1.25×10^{-8}	Release of the entire contents	152
Instantaneous failure of primary container	5×10^{-8}	Release of the entire contents into the intact outer shell	153
Failure of the primary container and outer shell	1.25×10^{-8}	Release of the entire contents in 10 minutes in a continuous and constant stream	154
Failure of the primary container	5×10^{-8}	Release of the entire contents in 10 minutes in a continuous and constant stream into the intact outer shell	155
Failure of primary container	1×10^{-4}	Continuous release from a hole with an effective diameter of 10 mm into the intact outer shell	156

Table 54: LOCs for double containment atmospheric storage tanks

3.6.7 MAJOR ACCIDENTS TO THE ENVIRONMENT IN THIS SECTOR

In addition to the measures in place to minimise the risks to people, adequate tertiary containment should be provided, so that the contents of the largest tank and all the expected extinguishing media can be contained in the event of a major fire.[24]

CLP Category 2 and Category 3 flammable liquids are generally more likely to carry an environmental hazard rating than Category 1 flammables. The most important major accident consideration for Category 3 storage is an LOC leading to a release of the dangerous substance into the environment.

Where the referral for TLUP advice relates to an application in the vicinity of these establishments, the applicant should consult with the operator on the consequences of a major accident and include an assessment in the application.

[24] EPA (2019) provides guidance on firewater retention.

3.7 Fertiliser storage installations

The main sources of off-site risk for this sector are associated with the blending/storage of fertiliser-grade ammonium nitrate (named substances 1 to 4 in Part 2 of Schedule 1 of the COMAH Regulations 2015). For TLUP purposes, the events to consider are a major fire leading to a plume of toxic smoke capable of travelling some distance off-site and also, if the fire leads on to a detonation, from blast overpressure effects.

Typically, the qualifying inventories at a fertiliser blending plant belong to Ammonium Nitrate Named Substance 2, which fulfils the resistance to detonation requirements of Regulation EC No 2003/2003 (with thresholds of 1250 and 5000 tonnes). This will be referred to as fertiliser-grade ammonium nitrate (FGAN).

Ammonium Nitrate Named Substances 1,3 and 4 are not normally encountered and are not addressed here.

As FGAN is not combustible, a major accident would have to be initiated by other sources; this could be a fire involving wood or other combustible material, or a road transport vehicle, for example. Local conditions (that is, the possibility of these contaminants being present) will influence the scenario probabilities.

The effect of fire on FGAN is to cause it to decompose, releasing toxic gases. The toxic gases modelled are NO and NO_2. Therefore, one scenario addresses off-site dispersion of these fire-generated gases.

FGAN detonation requires the formation of a pool of molten ammonium nitrate, caused by the heat input from a fire, a confined state and the initiation of an explosion by some mechanism (for example, from impact by a high-energy object). Due to the explosion resistance of FGAN, a route to detonation is extremely improbable and the accident frequencies reflect this. However, detonation following a fire on a truck is considered a more credible scenario. While missile generation following detonation is credible, the off-site risk of missile impact in any single location is judged to be small.

The most likely MATTE relates to a fire/fire-water run-off scenario: appropriate retention facilities should be in place.

3.7.1 APPROACH TO SOURCE TERMS

Where FGAN is stored on palletised stacks in the yard, then a fire scenario is considered. For fire modelling purposes, 300 tonnes (300 t) of FGAN (the maximum stack size recommended by good practice) is taken as the largest mass likely to be involved in a fire and therefore in subsequent detonation. For that purpose, it is taken to be equivalent to 42 tonnes (42 t) of trinitrotoluene (TNT). Therefore, 30 t FGAN is equivalent to 4.2 t TNT. Generally, smaller fires (10% of total mass) are considered to be almost two orders of magnitude more likely than fires involving the full inventory. Progression to detonation is considered to be almost two orders of magnitude less likely for the full 300 t stack than for 10% of the stack.

Fertiliser truck fires are modelled as involving the maximum possible inventory (~30 t) of palletised ammonium nitrate fertiliser (ANF) or, for loose material, the maximum inventory that can be carried by the truck.

When modelling the generation of fumes of toxic NO_2 from a fire inside a warehouse, the initial fire situation, before the roof collapses, is of most interest, due to the potential for higher ground-level concentrations. Once the fire develops and the roof collapses, the heat-induced buoyancy means that ground-level concentrations will be insignificant, except in very high winds.

The wind-stability pairs of F_2, D_5 are typically used for modelling. However, buoyancy calculations – Briggs lift-off criterion equation (Hanna *et al*. (1998)) – generally allow F_2 conditions to be discarded for modelling purposes. While D_{10} conditions could be included to account for high winds, a somewhat simpler approach is taken in the standard model, which gives a degree of conservatism to the resulting risk figures: the release is modelled as a passive dispersion in D_5 conditions, using a Gaussian model.

Toxic gas release rates in fires are as follows: 1.4 kg s^{-1} of NO_2 and 2.3 kg s^{-1} of NO for the worst-case (300 t) scenario.

The 1% fatality footprint can be taken to be equivalent to the particle deposition area, if required.

3.7.2 SCENARIOS AND FREQUENCY OF OCCURRENCE

In the standard model, FGAN is considered to be present all year round. The main accident scenarios considered are shown in Table 55.

LOC scenario	Frequency (yr^{-1})	Consequence	Frequency	Event #
Fire started in truck	4.02×10^{-4}	30 t detonation	4.02×10^{-5}	157
		30 t fire	3.62×10^{-4}	158
Fire started in a stack	1.98×10^{-4}	30 t fire	1.94×10^{-4}	159
		30 t explosion	1.96×10^{-6}	160
		300 t fire	1.96×10^{-6}	161
		300 t explosion	1.98×10^{-8}	162

Table 55: FGAN (Named Dangerous Substance 2) yard scenarios

Truck fire frequencies are given as per truck transporting FGAN. Allowance is made for the fraction of time the activity happens during a year. For example, assuming a truck delivery of bulk FGAN takes 15 minutes (0.25 of an hour) and there are 400 transports per year, this results in a frequency figure of $((0.25 \times 400)/8760) \times (4.02 \times 10^{-4})$, or 4.59×10^{-6} per year.

Fire frequency is per bulk stack per year, which can be adjusted for the fraction of a year that a bulk stack is present, as shown in Table 56.

For the warehouse (after assigning a frequency of 1.44×10^{-4} per year to non-escalating events):

LOC scenario	Frequency (yr^{-1})	Consequence	Frequency	Event #
Fire started in bulk stack	4.56×10^{-4}	30 t fire	4.47 × 10-4	163
		30 t explosion	4.51 × 10-6	164
		300 t fire	4.51 × 10-6	165
		300 t explosion	4.56 × 10-8	166

Table 56: FGAN (Named Dangerous Substance 2) warehouse scenarios

The fraction of the year that the bulk material is present should be factored into the calculation.

Risks sources are centred on the FGAN storage and operation areas.

The *Policy & Approach of the Health & Safety Authority to COMAH Risk-based Land-use Planning* (19 March 2010) described two methods for ANF sites. The first, on page 26, described a 'simple' approach involving five scenarios. In addition, Appendix 5 described a more detailed approach (illustrated by two event trees), giving nine events to be modelled. In contrast, this Guidance utilises just one approach to ANF scenario modelling. Ten consequence events are listed but, in reality, this can be reduced to four events – a 30 t fire plus explosion and a 300 t fire plus explosion – which are repeated at varying locations. Taking into account the simplicity and ease of the explosion element of modelling, this is not unreasonable and not out of line with the previous guidance.

3.8 Dangerous substance warehouses

Generally, the off-site risks associated with the most foreseeable accidents in chemical warehouses are negligible, as the quantities involved in any LOC tend to be limited (for example, single inventory containments up to about 0.2 m^3 for a single drum or 1 m^3 for an intermediate bulk container (IBC)). ISO road transport containers can be treated as described in Sections 3.1.2, 3.2.2, and 3.6.5 as appropriate. Particularly toxic substances (gases or volatile liquids) may require additional consideration (see Section 3.10).

Therefore, the most common off-site risk in this sector, for TLUP advice generation, is the risk associated with a major fire, involving the release of hazardous substances from multiple containers. This could lead to a plume of toxic smoke capable of travelling some distance.

Where there is significant storage of flammable substances, the near-field thermal effects of a fire should also be considered.

3.8.1 APPROACH TO SOURCE TERMS

Assuming that the warehouse does not contain any particularly toxic materials (such as pesticides or toxic agrochemicals capable of being released unburned in the fire plume), then the main risk will be associated with dispersion of toxic combustion products.

However, it is difficult to predict the precise mix and quantity of each toxic combustion product: the approach taken is to assume that the toxicity of the fire plume can be represented by an equivalent release rate of the most significant toxic combustion product. This could be, for example, nitrogen dioxide, hydrogen chloride, or sulphur dioxide, depending on the chemical substance composition within the warehouse.

Carbon monoxide and carbon dioxide could also be released in significant quantities, as they could in all fires involving organic substances; therefore, no emphasis is placed on assessing CO or CO_2 levels.

For warehouses storing complex mixtures of dangerous substances, representative release rates for NO_2, HCl, SO_2 and any other dominant toxic combustion products have to be determined. Porter *et al*. (2000) made the following useful general assumptions:

Contains	Toxic combustion product	Conversion rate (%)
N	NO_2	5
N	HCN	1.5
Cl	HCl	100
S	SO_2	100
Br	HBr	100

Table 57: Toxic combustion conversion rates

Therefore, in a fire involving a dangerous substance containing nitrogen, the release rate of NO_2 can be estimated by assuming that 5% of the nitrogen content (Table 57) of the dangerous substances stored in the warehouse is combusted to form NO_2 which is then dispersed.

Example: for a large warehouse storing 2500 tonnes of ammonium chloride (NH_4Cl), molecular weight (MW) = 53.49, the release rates of NO_2 (MW = 46) and HCl (MW = 36.46), from a major fire involving 100% of the inventory, can be calculated as follows (assuming 5% of N converted to NO_2, and 100% Cl converted to HCl, as shown in Table 57):

NO_2 release rate = 2,500,000 × (14/53.49 × 0.05) × (46/14) = 108,000 kg

HCl release rate = 2,500,000 × (35.45/53.49 × 1.0) × (36.46/35.45) = 1,699,200 kg

In most weather conditions, the hot plume of smoke from the fire will be buoyant, and is likely to rise into the atmosphere, resulting in relatively little risk at ground level. Therefore, for the purposes of TLUP risk assessment, it is necessary only to consider relatively high wind speed conditions, which generally occur for a small percentage of the time. However, as with fertiliser fires, the simpler and more conservative standard model approach is to model as a passive Gaussian dispersion in D_5 conditions.

The standard model assumes that, for a large warehouse, the fire inventory is released over 2 hours (but only the first 30 minutes of this are modelled for dose calculation), using a standard Gaussian plume model, with no plume rise.

So for our example, a fire in a large warehouse involving 100% of the inventory gives the following release rates:

NO_2 release = (108,000 / (2 × 60)) × 30 = 27,000 kg = 27,000 kg over 30 minutes = 15 kg/sec

HCL release = (1,699,200 / (2 × 60)) × 30 = 424,800 kg = 424,000 kg over 30 minutes = 236 kg/sec

Where several toxic combustion products arise from a fire, it will be necessary to consider the relative release rates and toxicities to determine whether a particular component is clearly dominant. Otherwise, it may be necessary to calculate an increased 'equivalent' release rate for the most significant component.

3.8.2 FIRE FREQUENCY

The likelihood of fire starts in typical warehouses has been estimated at about 10^{-2}/year, based on historical evidence (see Hymes and Flynn (1982) and Hockey and O'Donovan (1997)). However, the majority of such fires are relatively minor or are rapidly controlled and only a small proportion escalate to become major fires, with data from Hockey and O'Donovan suggesting a frequency of about 10^{-3}/year for a large fire in a typical warehouse. However, for the warehouse type holding hazardous substances, it is assumed that the more stringent controls would result in a reduction in the likelihood of such major events (involving the entire warehouse) being typically an order of magnitude lower still, at about 10^{-4} per year. The higher frequency of 10^{-3}/year is assigned to a lesser fire involving just 10% of the source term, which is the following:

Scenario	Frequency (yr^{-1})	Event #
Fire (10% of inventory)	1×10^{-3}	167
Fire (100% of inventory)	1×10^{-4}	168

Table 58: Fire frequency for warehouse

Warehouses with sprinklers are considered to have a reduced frequency of fire, but data supporting reduced frequency estimation are limited (Frank *et al*., 2013). For the standard model, small fire frequency is reduced by one order of magnitude and large fires by half of one order of magnitude, as shown in Table 59.

Scenario	Frequency (yr^{-1})	Event #
Fire (10% of inventory)	1×10^{-4}	169
Fire (100% of inventory)	5×10^{-4}	170

Table 59: Warehouse (sprinkler) fire frequencies

3.9 Chemical/Pharmaceutical installations

Chemical/pharmaceutical manufacturing/processing plants are likely to contain multiple hazard sources, often distributed around a large site. Hazards are likely to include those related to:

- bulk flammable storage,
- dangerous substance warehousing,
- bulk storage and processing of toxics and flammables,
- overpressure and explosion related to processing,
- releases from pressurised drums of toxic and flammable gases.

The risks associated with flammable storage and warehousing generally can be assessed using the methods described elsewhere in this document; therefore, only risks from process hazards are considered in more detail in this section. For sites with multiple hazards, risks should be aggregated.

A key point to note for chemical processing sites is that the dangerous substances in-process may be at elevated temperatures and pressures; therefore, the likelihood of relatively small releases leading to a significant major accident is considerably increased. Furthermore, the hazardous substances that could be released from a process may include reaction products (and by-products) and not simply the raw materials or intended final products.

The general methods outlined here can also be applied to other establishment types with process hazards and/or multiple hazards.

3.9.1 APPROACH

3.9.1.1 Risks from atmospheric bulk storage of toxic (and water-reactive) liquids

Section 3.6 addressed LOC scenarios related to the bulk storage of flammable liquids. For sites with atmospheric bulk storage of non-flammable toxic (or water-reactive) liquids, the same base LOC figures can be used, with modified consequences, as follows:

LOC scenario	Frequency (yr^{-1})	Consequence	Frequency	Event #
Instantaneous failure	5×10^{-6}	Pool evaporation + vapour dispersion (bund)	5×10^{-6}	171
		Pool evaporation + vapour dispersion (overtop)	5×10^{-6}	172
Failure over 10 minutes	5×10^{-6}	Pool evaporation + vapour dispersion	5×10^{-6}	173
10 mm pipe leak over 30 minutes	1×10^{-4}	Pool evaporation + vapour dispersion	1×10^{-4}	174

Table 60: LOC scenarios and frequencies for bulk toxic storage

Adequate bunds are assumed to be present, as required by good practice. For instantaneous failure, it is assumed that a pool forms outside the bund; by default this is assigned 50% of the tank contents. Overtop pools are assigned an upper pool diameter limit of 100 m.

Truck deliveries may also need to be considered, as described in Table 61.

LOC scenario	Frequency (yr^{-1})	Consequence	Frequency	Event #
Instantaneous failure	1×10^{-5}	Pool evaporation + vapour dispersion	1×10^{-5}	175
		Pool evaporation + vapour dispersion (if overtop is relevant)	1×10^{-5}	176
Failure over 10 minutes	5×10^{-7}	Pool evaporation + vapour dispersion	5×10^{-7}	177

Table 61: Road tanker delivery LOCs

In addition, the scenarios in Table 62 can be taken into account for loading/unloading operations:

LOC scenario	Arm – Frequency (hr^{-1}) – Hose		Event #
Rupture of loading/ unloading arm/hose	3×10^{-8}	4×10^{-6}	178
Leak of loading/ unloading arm/hose 10%	3×10^{-7}	4×10^{-5}	179

Table 62 Road tanker loading/unloading LOCs

Additionally, failure due to LOC in a domino effect during unloading has to be included as in Table 63.

LOC scenario	Frequency (hr^{-1})	Event #
Pool evaporation	5.8×10^{-9}	180

Table 63 Road tanker domino toxic LOC

Evaporation release rates from pools can be calculated using standard evaporation models (in D_5 and F_2 conditions). More detailed calculations may be required for water-reactive chemicals or fuming acids.

3.9.1.2 Process risks

A full QRA to consider every process and every vessel individually would entail considerable effort and analysis, which is not considered necessary for the purposes of generating generic TLUP advice. Many of the possible LOC events will have immediate impacts within the process building which are not relevant to LUP. Therefore, the approach taken in the standard model is to identify the process step with the greatest potential for off-site consequences and to assume that this inventory bounds all other potential toxic and flammable events from the process building. This may require detailed analysis of the toxicity, flammability, volatility, temperature, and inventory for various cases in order to ensure that the worst-case toxic release is identified. The frequency of this event is then multiplied by the potential number of active process reaction vessels, in order to get the overall frequency for the LOC event. The locus of the releases is spread across the vessels.

Processes may be at elevated temperature and/or pressure and therefore the quantity of material that may be dispersed could be much greater than for an ambient release at atmospheric pressure. In some cases, it may be appropriate to assume that 100% of the available inventory in the largest vessel is released. In other cases, it may be possible to determine a smaller 'worst-case' source term.

In the absence of more detailed information, the likelihood of such a major release from a process vessel – allowing that other items of equipment (for example, pipes, pumps, compressors, heat exchangers) could also be sources of LOC events – is assumed to be equivalent to the 10-minute or 10 mm hole releases, as shown in Table 64.

LOC scenario	Frequency	Event #
Instantaneous release	5×10^{-6}	181
Release over 10 minutes	1×10^{-5}	182
Release through 10 mm pipe	5×10^{-4}	183

Table 64: LOC scenarios for process vessels (per vessel per year)

The figures are derived from the LOC frequencies in Table 30 (Module C) of RIVM 2020. The frequencies for the 10-minute release and the 10-mm release have been increased to compensate for releases from associated process equipment, which are not being separately modelled.

The LOCs from Table 64 should be multiplied by the number of reactor vessels in the hall or building, as appropriate. Dispersion should be modelled in D_5 and F_2 weather conditions. In most cases, a standard Gaussian plume model will be sufficient for modelling the dispersion.

For flammable substances, fire and explosion risk must be accounted for in the event tree. Events to be considered are:

- risk of VCE due to release of flammables in semi-confined regions, and
- flash fire.

These events will be included in the analysis unless it is clearly evident that such events are not applicable to the facility.

Therefore, the event assumed is a vapour or two-phase release external to the process building. If flammable, a flash fire is considered. If significant confinement is possible, a VCE is considered. If the substance also has toxic properties, then some of the flash fire probability is assigned to the toxic arm. For substances with a toxic hazard designations, all the risk is assigned to toxic dispersion.

A MATTE could also be an outcome. While not usually relevant in setting LUP zones or CDs, it would be relevant for a new establishment and the requirement for suitable barriers to eliminate possible accident pathways.

The risk associated with failure of pressure vessels can be calculated by assessing the blast overpressure that would be produced in the event of the worst-case pressure vessel failure (taking into account the volume and failure pressure). The failure pressure is typically taken as three times the design pressure. The overpressures will be determined using a simple TNT equivalence model, based on the release of stored energy in the vessel.

The risk associated with potential VCEs in semi-confined areas, such as might occur due to a leak of hot solvent, can be estimated simply by using the TNO vapour cloud explosion model, where the size of the flammable cloud is taken to correspond to the volume of the semi-confined region where the release may occur (often taken as the building volume). The ignition strength is taken as 7. For TLUP contour generation, VCEs inside some process buildings may be modelled using a TNO strength of 10, at the discretion of the CCA.

Where the potential for exothermic runaway exists, the instantaneous release LOC in Table 64 should be increased to 1 x 10^{-5} per year.

3.10 Gas drum and cylinder installations

The risks associated with dangerous substance gas drum and cylinder stores (including acetylene (C_2H_2), chlorine (Cl_2), hydrogen chloride (HCl), and ammonia (NH_3)), arise from the toxic and/or flammable gas and vapour that is generated from any loss from the pressurised containment. The released inventory is limited to that of the containing cylinder or drum (a drum has a volume greater than 150 L). The likelihood of release can be relatively high due to the nature of the manual operations involved in handling drums.

RIVM (2020) suggests the following scenarios and frequencies for pressurised containment of (water) volumes up to 150 L:

Scenario	Frequency (yr^{-1})	Event #
Instantaneous release	5×10^{-7}	184
Release through hole D=3.3 mm	5×10^{-7}	185

Table 65: LOC scenarios and event frequencies for pressurised cylinders (per cylinder per year)

For a multiple cylinder array with N cylinders, the following applies:

Scenario	Frequency (yr^{-1})	Event #
Instantaneous release	$N \times (5 \times 10^{-7})$	186
Release through hole D=3.3 mm	$N \times (5 \times 10^{-7})$	187

Table 66: LOC scenarios for pressurised cylinder array with N cylinders (per array, per year)

Dispersion of the toxic releases will be modelled in D_5 and F_2 weather conditions, using an appropriate dispersion modelling programme (such as ADAM, ALOHA, EFFECTS/RISKCURVES, PHAST).

For pressurised flammable gas cylinders, fire/explosion events will be modelled. Conditional probabilities are taken as:

Event	Conditional probability
Fireball/Jet fire	0.1
Flash fire	0.36
VCE	0.54

Table 67: Conditional probabilities for fire and explosion events

Drums are mobile pressurised containers of greater than 150 L water volume. The drum scenarios to be considered are for those for pressurised storage units and are listed in Table 68.

Scenario	Frequency (yr^{-1})	Event #
Instantaneous release	5×10^{-6}	188
Contents released over 10 minutes	5×10^{-6}	189
Release through pipe D=10 mm	1×10^{-4}	190

Table 68: LOC scenarios and event frequencies for pressurised drums (per drum per year)

3.11 Explosives handling/storage installations

This section applies to sectors manufacturing, storing or using explosives. This includes actual explosives manufacturing sites and sites using explosives (underground mines, for example).

The major accident scenarios associated with such sites are accidental detonation, giving rise to blast overpressure. Such explosions can also generate flying debris and cause window damage, which may sometimes be important in determining the LUP risk.

3.11.1 APPROACH TO MODELLING

Processing, storage and transport areas are considered as potential fire locations. Fires are considered to always lead on to an explosive event. The TNT equivalence model is used to determine the overpressure. The indoor and outdoor fatality fractions of the Explosives Storage and Transport Committee (ESTC) Model (UK Health and Safety Executive, 2002) may be applied.

The risk-based approach considers the worst-case scenario for each explosives inventory and assumes the following:

Scenario	Frequency (yr^{-1})	Event #
Fire in process building	1×10^{-4}	191
Fire in storage area	1×10^{-5}	192

Table 69: Scenarios for explosives

Fires involving 10% of the inventory are considered to have a probability of 0.9, with fires involving the full inventory to have a probability of 0.1.

Fatality and damage levels are calculated as described in Section 2.4.

3.12 Ammonia refrigeration plant

Releases can occur from vessels, pipes, pumps, condensers and evaporators in ammonia plants. Releases can be emitted into the plant building or directly into the open air.

Ammonia will be at varying pressures and temperatures in the different parts of a refrigeration system: the pressure and temperature conditions determine the source term at each potential release point.

For the standard TLUP case, a simplified approach is taken, using a limited set of scenarios. These are:

- Instantaneous release of one-third of the largest inventory through a pipe over 10 minutes, outdoors, at a temperature of -12 °C and at a frequency of 5×10^{-6} per year. The maximum pool diameter is set to 100 m.
- Failure during bulk ammonia truck delivery, taken as 1×10^{-6} per delivery.
- The ammonia probit listed in Table 16 is used to estimate fatality risk from modelled (D_5/F_2) concentrations.

3.13 Distilleries and spirit maturation warehouses

The information in this section applies to sectors manufacturing and/or storing potable spirits.

Processing, storage (including tank farms) and transport locations are considered as potential fire locations. The major accident scenarios associated with such sites are spirit warehouse fires, fire and explosion in still houses or at bulk loading/unloading points.

3.13.1 APPROACH TO MODELLING

Uncertainty exists as to the SEP of potable spirit fires. A Swedish study[25] on large-scale ethanol fires of bulk mixtures, with added small fractions of gasoline, noted that the thermal flux to a receiver is higher than previously predicted and much higher from an ethanol fire than from an equivalent gasoline fire.

A subsequent UK Health and Safety Executive Research Report[26] agreed that the flux from ethanol fires is high and concluded that the data obtained from the ETANK project formed a reasonable basis for risk assessment.

For cask-strength whiskey (65% alcohol by volume), it concluded that the SEP of such fires is less than for 100% ethanol. It concluded that much larger experiments would be necessary in order to provide the data to support more realistic assessments.

Neither report provided guidance on modelling of warehouse fires in which wooden casks make a contribution to the fire load. Therefore, care is required in modelling fire events at distilleries and spirit warehouses.

In the standard TLUP approach, the model described by Rew (Rew *et al*, 1997) or an equivalent model will be used to determine incident heat flux from ethanol fires.

Lower SEPs will be assumed for aqueous solutions and cask-strength whiskey fires.

However, for fires in warehouses containing wooden casks, the maximum SEP used is increased to 250 kw/m^2 (UK Health and Safety Executive, 2001), due to the substantial co-burning of wooden casks, which is assumed to considerably add to the fire load.

Ethanol has a flash point of 12 °C and boils at 78.4 °C and is therefore located in CLP Category 2 at ambient temperatures: this means that it falls into Ignition Category 2 (see Figure 8).

[25] ETANKFIRE – Experimental results of large ethanol fuel pool fires, SP Report 15:12 (SP Technical Research Institute of Sweden, 2015)

[26] RR 1144 – Measurements of burning rate and radiative heat transfer for pools of ethanol and cask-strength whisky (UK Health and Safety Executive, 2019)

Scenarios for bulk ethanol storage are:

LOC scenario	Frequency (yr-1)	Consequence	Frequency	Event #
Instantaneous failure	5×10^{-6}	Pool fire	5×10^{-8}	193
		None/Toxic/MATTE	4.95×10^{-6}	194
Failure over 10 minutes	5×10^{-6}	Pool fire	5×10^{-8}	195
		None/Toxic/MATTE	4.95×10^{-6}	196
10 mm pipe leak over 30 minutes	1×10^{-4}	Pool fire	1×10^{-6}	197
		None/Toxic/MATTE	9.9×10^{-5}	198

Table 70: Bulk ethanol storage LOCs

As with all instantaneous bulk storage failures, overtopping of a bund leading to a pool fire external to the bund is a credible scenario.

Ethanol releases occurring at, or close to, the boiling point (from a still for example) are treated as being in Ignition Category 1. In the standard case, the failure frequencies listed in RIVM 2020 for distillation columns are, for simplicity, further increased to cover the failures of associated condensers, reboilers and pumps. The still scenarios are listed in Table 71.

LOC scenario	Frequency (yr-1)	Consequence	Frequency	Event #
Instantaneous failure	5×10^{-5}	Pool fire	8.86×10^{-6}	199
		VCE	1.87×10^{-5}	200
		Flash fire	5.61×10^{-6}	201
		None/Toxic/MATTE	1.68×10^{-5}	202
Failure over 10 minutes	5×10^{-5}	Pool fire	8.86×10^{-6}	203
		VCE	1.87×10^{-5}	204
		Flash fire	5.61×10^{-6}	205
		None/Toxic/MATTE	1.68×10^{-5}	206
10 mm pipe leak over 30 minutes	1×10^{-3}	Pool fire	1.77×10^{-4}	207
		VCE	3.74×10^{-4}	208
		Flash fire	1.12×10^{-4}	209
		None/Toxic/MATTE	3.37×10^{-4}	210

Table 71: Ethanol still LOCs

Potential MATTEs are spirit spills or firewater getting into watercourses. Pool fires in firewater retention facilities will also be considered.

Bulk road tanker loading/unloading is assumed to involve inventories up to 30 m^3. Spills during loading/unloading are credible. For resulting pool fires, the area of the largest possible pool is used (bearing in mind that this may be severely limited through kerbing and drainage and for modelling purposes never exceeds a diameter of 100 m). The event frequencies in Table 72 are applicable to bulk loading/unloading of potable spirits.

LOC scenario	Frequency (yr^{-1})	Consequence	Frequency	Event #
Instantaneous failure	1×10^{-5}	Pool fire	1×10^{-7}	211
		None/Toxic/MATTE	9.9×10^{-6}	212
Leak largest connection	5×10^{-7}	Pool Fire	5×10^{-9}	213
		None/Toxic/MATTE	4.95×10^{-8}	214

Table 72: Event frequencies for potable spirits road tankers

The frequencies should be adjusted for the proportion of the year that the road tanker is present.

In addition, the scenarios in Table 73 are taken into account for loading/unloading operations:

LOC scenario	Arm – Frequency (hr^{-1}) – Hose		Event #
Rupture of loading/ unloading arm/hose	3×10^{-8}	4×10^{-6}	215
Leak of loading/ unloading arm/hose 10% Ø	3×10^{-7}	4×10^{-5}	216

Table 73: Road tanker loading/unloading LOCs

Moreover, failure due to a road tanker domino effect may also be included, as Table 74 shows.

LOC scenario	Frequency (hr^{-1})	Event #
Pool fire	5.8×10^{-9}	217

Table 74: Road tanker domino effect pool fire

Spirit warehouses are typically well protected against vandalism and arson. In addition, they are compartmented and (in most cases) they contain sprinklers.

For these reasons, and provided that such measures are in place, the major warehouse fire frequency is set at:

LOC scenario	Frequency (yr^{-1})	Event #
Full compartment warehouse fire	5×10^{-6}	218

Table 75: Spirit warehouse fire frequency (with sprinklers)

If the warehouse is without sprinklers, the frequency is increased to 5×10^{-5} per year.

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Appendix 1

Request to the HSA for TLUP advice

Please complete this form prior to sending a request for technical land use planning advice to the Health & Safety Authority. Then send it to the dedicated HSA Land Use Planning mailbox: LandUsePlanning@hsa.ie

Note: This form is not required for Development Plan referrals, they can be sent directly to the email address above.

Planning Authority: SELECT PLANNING AUTHORITY

Type of referral (tick): Request for technical advice ☐ Strategic Infrastructure ☐ Planning Appeal ☐ Large Scale Residential Development ☐ Section 5 Declaration ☐

For all referrals, please select the development type and relevant establishment below:

This development type is (tick):

a. related to a modification to an existing establishment or ☐

b. external, within the consultation distance notified to us by the HSA or ☐

c. for a new establishment ☐

d. unsure if covered by the COMAH Regulations, can you advise? Further details attached. ☐

Relevant establishment SELECT ESTABLISHMENT

If the development refers to type b, tick **one** of the following: the development category is:

1	a. Provision of hotel, hostel or holiday accommodation	☐
	b. Provision of housing	☐
2	Provision of schools, crèches or other educational or childcare facilities, training centres, hospitals, convalescent homes, homes for the elderly, or sheltered accommodation.	☐
3	Retail development greater than **250 m²** in gross floor space.	☐
4	Structures for community and leisure facilities, greater than **100 m²** in gross floor space.	☐
5	Provision of facilities or use of land for activities likely to attract occasionally more than **1,000** people at any one time.	☐
6	Commercial, industrial or office development designed to accommodate **20 or more** employees.	☐
7	Provision of parking facilities (on its own) for more than **200 motor vehicles**.	☐
8	A major transport link (including a public road).	☐
9	Any development adjoining or separated only by a road from an establishment, posing an above-normal risk of fire or explosion.	☐
10	Modifications to any of the above, which will increase the number of persons present by **10 or more**.	☐

The generic advice provided by the HSA is insufficient for the planning authority in this case because (if applicable):

Relevant reference details:

Planning authority reference:

Link to location of all documents relevant to planning application:

Date by which decision is due:

Appendix 2

Development sensitivity levels

SENSITIVITY LEVEL 1: People at work, Car Parks

Level 1

DT1.1 – Workplaces

DT1.2 – Parking areas

DEVELOPMENT TYPE	EXAMPLES	DEVELOPMENT DETAIL AND SIZE	JUSTIFICATION
WORKPLACES (DT 1.1)	Offices, factories, warehouses, haulage depots, farm buildings, non-retail markets, builder's yards.	Workplaces (predominantly non-retail), providing for fewer than 100 occupants in each building **and** fewer than three occupied storeys – **Level 1**	Places where the occupants will be fit and healthy, and could be organised easily for emergency action. Members of the public will not be present or will be present in very small numbers and for a short time.
	EXCLUSIONS		
		Workplaces (predominantly non-retail) providing for 100 or more occupants in any building **or** 3 or more occupied storeys in height **(DT 1.1.1)** **Level 2** (except where the development is at the major hazard site itself, where it remains Level 1).	Substantial increase in numbers at risk with no direct benefit from exposure to the risk.
	Rehabilitation and training services for people with disabilities.	Workplaces (predominantly non-retail) specifically for people with disabilities – **(DT 1.1.2)** **Level 3**	Those at risk may be especially vulnerable to injury from hazardous events and/or they may not be able to be organised easily for emergency action.
PARKING AREAS	Car parks, truck parks, lock-up garages.	Parking areas with no other associated facilities (other than toilets) – **Level 1**	
	EXCLUSIONS		
	Car parks with picnic areas, or at a retail or leisure development, or serving a park and ride facility.	Where parking areas are associated with other facilities and developments the sensitivity level and the decision will be based on the facility or development. **(DT 1.2.1)**	

Appendix 2

Development sensitivity levels

SENSITIVITY LEVEL 2: Developments for use by the general public

Level 2

DT2.1 – Housing

DT2.2 – Hotel/Hostel/Holiday accommodation

DT2.3 – Transport links

DT2.4 – Indoor use by public

DT2.5 – Outdoor use by public

DEVELOPMENT TYPE	EXAMPLES	DEVELOPMENT DETAIL AND SIZE	JUSTIFICATION
HOUSING **(DT 2.1)**	Houses, apartments, retirement flats/ bungalows, residential caravans, mobile homes.	Developments up to and including 30 dwelling units **and** at a density of no more than 40 per hectare – **Level 2.**	Development where people live or are temporarily resident. It may be difficult to organise people in the event of an emergency.
	EXCLUSIONS		
	Infill, backland development (development of land at rear of existing property).	Developments of one or two dwelling units **(DT 2.1.1)** – **Level 1**	Minimal increase in numbers at risk.
	Larger housing developments	Larger developments for more than 30 dwelling units **(DT 2.1.2)** – **Level 3**	Substantial increase in numbers at risk
	Developments at high density.	Any developments (for more than two dwelling units) at a density of more than 40 dwelling units per hectare – **(DT 2.1.3)** **Level 3**	High-density developments.
HOTEL/HOSTEL/ HOLIDAY ACCOMMODATION **(DT 2.2)**	Hotels, motels, guesthouses, hostels, youth hostels, holiday camps, holiday homes, student accommodation, accommodation centres, holiday caravan sites, camping sites.	Accommodation of up to 100 beds or 33 caravan/tent pitches – **Level 2.**	Development where people are temporarily resident. It may be difficult to organise people in the event of an emergency.

SENSITIVITY LEVEL 2: Developments for use by the general public *Continued*

Level 2

DEVELOPMENT TYPE	EXAMPLES	DEVELOPMENT DETAIL AND SIZE	JUSTIFICATION
	EXCLUSIONS		
HOTEL/HOSTEL/ HOLIDAY ACCOMMODATION (DT 2.2)	Smaller guesthouses, hostels, youth hostels, holiday homes, student accommodation, holiday caravan sites, camping sites.	Accommodation of fewer than 10 beds or three caravan/tent pitches – **Level 1**	Minimal increase in numbers at risk.
	Larger hotels, motels, hostels, youth hostels, holiday camps, holiday homes, halls of residence, dormitories, holiday caravan sites, camping sites.	Accommodation of more than 100 beds or 33 caravan/tent pitches – **(DT 2.2.2)** **Level 3**	Substantial increase in numbers at risk.
TRANSPORT LINKS (DT 2.3)	Motorway, dual carriageway.	Major transport links in their own right, i.e. not as an integral part of other developments – **Level 2.**	Prime purpose is as a transport link. Potentially large numbers exposed to risk, but exposure of an individual is only for a short period.
	EXCLUSIONS		
	Estate roads, access roads.	Single-carriageway roads – **(DT 2.3.1)** **Level 1**	Minimal numbers present and exposed to risk for a short time period (predominantly). Associated with other development.
	Any rail or tram track.	Railways – **(DT 2.3 × 2)** **Level 1**	Transient population, exposed to risk for short time periods. Times with no population present.

Appendix 2

Development sensitivity levels

SENSITIVITY LEVEL 2: Developments for use by the general public *Continued*

Level 2

DEVELOPMENT TYPE	EXAMPLES	DEVELOPMENT DETAIL AND SIZE	JUSTIFICATION
INDOOR USE BY PUBLIC **(DT 2.4)**	**Food and drink:** Restaurants, cafés, drive-through fast food, pubs. **Retail:** Shops; petrol filling stations (total floor space based on shop area, not forecourt); vehicle dealers (total floor space based on showroom/sales building not outside display areas); retail warehouses; super-stores; small shopping centres; markets; financial and professional services to the public. **Community and adult education:** Libraries, art galleries, museums, exhibition halls, day surgeries, health centres, religious buildings, community centres. Adult education, second-level education colleges, colleges of further education. **Assembly and leisure:** Coach/bus/railway stations, ferry terminals, airports. Cinemas, concert/bingo/dance halls. Conference centres. Sports/ leisure centres, sports halls. Facilities associated with golf courses, flying clubs (e.g. changing rooms, club house), indoor go-kart tracks.	Developments for use by the general public where total floor space is from 250m² up to 5000m² - **Level 2.**	Developments where members of the public will be present (but not resident). Emergency action may be difficult to coordinate.
	EXCLUSIONS		
		Development with less than 250 m² total floor space – **(DT 2.4.1)** **Level 1**	Minimal increase in numbers at risk.

SENSITIVITY LEVEL 2: Developments for use by the general public *Continued*

Level 2

DEVELOPMENT TYPE	EXAMPLES	DEVELOPMENT DETAIL AND SIZE	JUSTIFICATION
INDOOR USE BY PUBLIC **(DT 2.4)**		Development with more than 5000 m² total floor space – (DT 2.4.2) **Level 3**	Substantial increase in numbers at risk.
OUTDOOR USE BY PUBLIC **(DT 2.5)**	**Food and drink:** Food festivals, picnic area. **Retail:** Outdoor markets, car boot sales, funfairs. **Community and adult education:** Open-air theatres and exhibitions. **Assembly and leisure:** Coach/bus/railway stations, park and ride facilities, ferry terminals. Sports stadia, sports fields/pitches, funfairs, theme parks, viewing stands. Marinas, playing fields, children's play areas, BMX/go-kart tracks. Country parks, nature reserves, picnic sites, marquees.	Principally an outdoor development for use by the general public, i.e. developments where people will predominantly be outdoors and not more than 100 people will gather at the facility at any one time – **Level 2.**	Developments where members of the public will be present (but not resident) either indoors or outdoors. Emergency action may be difficult to coordinate.
	EXCLUSIONS		
	Outdoor markets, car boot sales, funfairs. Picnic area, park and ride facilities, viewing stands, marquees.	Predominantly open-air developments likely to attract the general public in numbers greater than 100 people, but up to 1,000 people at any one time – **(DT 2.5.1)** **Level 3**	Substantial increase in numbers at risk and more vulnerable due to being outside.
	Theme parks, funfairs, large sports stadia and events, open-air markets, outdoor concerts, pop festivals.	Predominantly open-air developments likely to attract the general public in numbers greater than 1,000 people at any one time – **(DT 2.5.2)** **Level 4**	Very substantial increase in numbers at risk, more vulnerable due to being outside and emergency action may be difficult to coordinate.

Appendix 2

Development sensitivity levels

SENSITIVITY LEVEL 3: Developments for use by vulnerable people

Level 3

DT3.1 – Institutional accommodation and education

DT3.2 – Prisons

DEVELOPMENT TYPE	EXAMPLES	DEVELOPMENT DETAIL AND SIZE	JUSTIFICATION
INSTITUTIONAL ACCOMMODATION AND EDUCATION **(DT3.1)**	Hospitals, convalescent homes, nursing homes. Housing for elderly with warden on-site or 'on call', sheltered housing. Nurseries, crèches. Schools and academies for children up to school-leaving age.	Institutional, educational and special accommodation for vulnerable people, or that provides a protective environment – **Level 3.**	Places providing an element of care or protection. Due to age, infirmity or state of health, the occupants may be especially vulnerable to injury from hazardous events. Emergency action and evacuation may be very difficult.
	EXCLUSIONS		
	Hospitals, convalescent homes, nursing homes, sheltered housing.	24-hour care where the site on the planning application being developed is greater than 0.25 hectare **(DT3.1.1)** **Level 4**	Substantial increase in numbers of vulnerable people at risk.
	Schools, nurseries, crèches.	Day care where the site on the planning application being developed is greater than 1.4 hectares **(DT3.1.2)** – **Level 4**	Substantial increase in numbers of vulnerable people at risk.
Places of detention **(DT3.2)**	Prisons, detention facilities, remand centres.	Secure accommodation for those sentenced by court, or awaiting trial, etc. – **Level 3.**	Places providing detention. Emergency action and evacuation may be very difficult.

SENSITIVITY LEVEL 4: Very large and sensitive developments

Level 4

DT4.1 - Institutional accommodation

DT4.2 - very large outdoor use by public

DEVELOPMENT TYPE	EXAMPLES	DEVELOPMENT DETAIL AND SIZE	JUSTIFICATION
		EXCLUSIONS	
INSTITUTIONAL ACCOMMODATION (DT4.1)	Hospitals, convalescent homes, nursing homes, sheltered housing.	Large developments of institutional and special accommodation for vulnerable people (or that provide a protective environment) where 24-hour care is provided. And where the site on the planning application being developed is greater than 0.25 hectare: **Level 4.**	Places providing an element of care or protection. Due to age or state of health, the occupants may be especially vulnerable to injury from hazardous events. Emergency action and evacuation may be very difficult. The risk to an individual may be small, but there is a larger societal concern.
	Nurseries, crèches. Schools for children up to school-leaving age.	Large developments of institutional and special accommodation for vulnerable people (or that provide a protective environment) where day care (not 24-hour care) is provided. And where the site on the planning application being developed is greater than 1.4 hectares: **Level 4.**	Places providing an element of care or protection. Due to their age, the occupants may be especially vulnerable to injury from hazardous events. Emergency action and evacuation may be very difficult. The risk to an individual may be small, but there is a larger societal concern.
VERY LARGE OUTDOOR USE BY PUBLIC (DT4.2)	Theme parks, large sports stadia and events, open-air markets, outdoor concerts, and pop festivals.	Predominantly open-air developments where there could be more than 1,000 people present **Level 4.**	People in the open air may be more exposed to toxic fumes and thermal radiation than if they were in buildings. Large numbers make emergency action and evacuation difficult. The risk to an individual may be small, but there is a larger societal concern.

Notes

1. Where a development straddles zones, the development will be considered to belong to the zone that gives rise to the greatest expectation value (EV) – a societal risk assessment may be necessary if there is significant expectation contribution from the other zone(s). For developments consisting of multiple development types, a societal risk evaluation will likely be necessary.

Appendix 3

Development type by zone

Developments not advised against for each zone are presented in this appendix.

The overall scheme is:

	Inner Zone (Zone 1)	Middle Zone (Zone 2)	Outer Zone (Zone 3)
Level 1	✓	✓	✓
Level 2	✗	✓	✓
Level 3	✗	✗	✓
Level 4	✗	✗	✗

Inner zone (individual risk ≥ 10^{-5} per year):

Zone	DEVELOPMENT DETAIL AND SIZE	EXAMPLES	DEVELOPMENT TYPE	DEVELOPMENT REF
1	Developments of one or two dwelling units.	Infill, backfill development (development of land at rear of existing property).	Housing	2.1.1
1	Accommodation of fewer than 10 beds or three caravan/tent pitches.	Smaller guesthouses, hostels, youth hostels, holiday homes, student accommodation, holiday caravan sites, camping sites.	Hotel/Hostel/ Holiday accommodation	2.2.1
1	Single-carriageway roads.	Estate roads, access roads.	Transport links	2.3.1
1	Railways.	Any railway or tram track.	Transport links	2.3.2
1	Development with less than 250 m² total floor space.		Indoor use by the public	2.4.1
1	Workplaces (predominantly non-retail), providing for fewer than 100 occupants in each building **and** fewer than three occupied storeys.	Offices, factories, warehouses, haulage depots, farm buildings, non-retail markets, builder's yards.	Workplaces	1.1
1	Parking areas with no other associated facilities (other than toilets).	Car parks, truck parks, lock-up garages.	Parking area	1.2

Appendix 3

Development type by zone

Middle zone (individual risk less than 10^{-5} and greater than or equal to 10^{-6} per year):

Zone	DEVELOPMENT DETAIL AND SIZE	EXAMPLES	DEVELOPMENT TYPE	REF
2	Developments up to and including 30 dwelling units **and** at a density of no more than 40 per hectare.	Houses, apartments, retirement flats/ bungalows, residential caravans, mobile homes.	Housing	2.1
2	Accommodation of up to 100 beds or 33 caravan/tent pitches.	Hotels, motels, guesthouses, hostels, youth hostels, holiday camps, holiday homes, student accommodation, accommodation centres, holiday caravan sites, camping sites.	Hotel/Hostel/ Holiday accommodation	2.2
2	Major transport links in their own right, i.e. not as an integral part of other developments.	Motorway, dual carriageway.	Transport links	2.3
2	Developments for use by the general public where total floor space is from 250 m² up to 5000 m².	**Retail:** Restaurants, cafés, drive-through fast food, pubs. **Food and Drink:** Shops; petrol filling station (total floor space based on shop area, not forecourt); vehicle dealers (total floor space based on showroom/sales building not outside display areas); retail warehouses; super-stores; small shopping centres; markets; financial and professional services to the public.	Indoor use by the public	2.4
2	Developments for use by the general public where total floor space is from 250 m² up to 5000 m².	**Community and adult education:** Libraries, art galleries, museums, exhibition halls, day surgeries, health centres, religious buildings, community centres. Adult education, second-level education colleges, colleges of further education.	Indoor use by the public	2.4
2	Developments for use by the general public where total floor space is from 250 m² up to 5000m².	**Assembly and leisure:** Coach/bus/railway stations, ferry terminals, airports. Cinemas, concert/ bingo/dance halls. Conference centres. Sports/leisure centres, sports halls. Facilities associated with golf courses, flying clubs (e.g. changing rooms, club house), indoor go-kart tracks.	Indoor use by the public	2.4

Appendix 3

Development type by zone

Middle zone (individual risk less than 10^{-5} and greater than or equal to 10^{-6} per year):

Zone	DEVELOPMENT DETAIL AND SIZE	EXAMPLES	DEVELOPMENT TYPE	REF
2	Principally an outdoor development for use by the general public, i.e. developments where people will predominantly be outdoors and not more than 100 people will gather at the facility at any one time.	**Food and drink:** Food festivals, picnic area.	Outdoor use by the public	2.5
2	Principally an outdoor development for use by the general public, i.e. developments where people will predominantly be outdoors and not more than 100 people will gather at the facility at any one time.	**Retail:** Outdoor markets, car boot sales, funfairs.	Outdoor use by the public	2.5
2	Principally an outdoor development for use by the general public, i.e. developments where people will predominantly be outdoors and not more than 100 people will gather at the facility at any one time.	**Community and adult education:** Open-air theatres and exhibitions.	Outdoor use by the public	2.5
2	Principally an outdoor development for use by the general public, i.e. developments where people will predominantly be outdoors and not more than 100 people will gather at the facility at any one time.	**Assembly and leisure:** Coach/bus/railway stations, park and ride facilities, ferry terminals. Sports stadia, sports fields/pitches, funfairs, theme parks, viewing stands. Marinas, playing fields, children's play areas, BMX/go-kart tracks. Country parks, nature reserves, picnic sites, marquees.	Outdoor use by the public	2.5
2	Workplaces (predominantly non-retail) providing for 100 or more occupants in any building **or** three or more occupied storeys in height.	(Except where the development is at the major hazard site itself, where it remains Level 1).	Workplaces	1.1.1

Appendix 3

Development type by zone

Outer zone (individual risk less than 10^{-6} and greater than or equal to 10^{-7} per year):

Zone	DEVELOPMENT DETAIL AND SIZE	EXAMPLES	DEVELOPMENT TYPE	REF
3	Larger developments for more than 30 dwelling units.	Larger housing developments.	Housing	2.1.2
3	Any developments (for more than two dwelling units) at a density of more than 40 dwelling units per hectare.	Developments at high density.	Housing	2.1.3
3	Accommodation of more than 100 beds or 33 caravans/tent pitches.	Larger – hotels, motels, hostels, youth hostels, holiday camps, holiday homes, halls of residence, dormitories, holiday caravan sites, camping sites.	Hotel/Hostel/ Holiday accommodation	2.2.2
3	Development with more than 5000 m^2 total floor space.		Indoor use by the public	2.4.2
3	Predominantly open-air developments likely to attract the general public in numbers greater than 100 people, but up to 1,000 people at any one time.	Outdoor markets, car boot sales, funfairs. Picnic area, park and ride facilities, viewing stands, marquees.	Outdoor use by the public	2.5.1
3	Workplaces (predominantly non-retail) specifically for people with disabilities.	Rehabilitation and training services for people with disabilities.	Workplaces	1.1.2
3	Institutional, educational and special accommodation for vulnerable people, or that provides a protective environment.	Hospitals, convalescent homes, nursing homes. Housing for elderly with warden on-site or 'on call', sheltered housing. Nurseries, crèches. Schools and academies for children up to school-leaving age.	Institutional accomodation and education	3.1
3	Secure accommodation for those sentenced by court, or awaiting trial.	Prisons, detention facilities, remand centres.	Places of detention	3.2

Appendix 3

Development type by zone

Developments requiring special assessment:

Zone	DEVELOPMENT DETAIL AND SIZE	EXAMPLES	DEVELOPMENT TYPE	DEVELOPMENT REF
	Large developments of institutional and special accommodation for vulnerable people (or that provide a protective environment) where 24-hour care is provided. And where the site on the planning application being developed is greater than 0.25 hectare.	Hospitals, convalescent homes, nursing homes, sheltered housing.	Institutional accommodation	3.1.1
	Large developments of institutional and special accommodation for vulnerable people (or that provide a protective environment) where day care (not 24-hour care) is provided. And where the site on the planning application being developed is greater than 1.4 hectares.	Nurseries, crèches. Schools for children up to school-leaving age.	Institutional accommodation	3.1.2
	Predominantly open-air developments where there could be more than 1,000 people present.	Theme parks, large sports stadia and events, open-air markets, outdoor concerts, and pop festivals.	Developments requiring special assessment	2.5.2

A planning authority has received generic TLUP advice from the CCA for an establishment in its area.

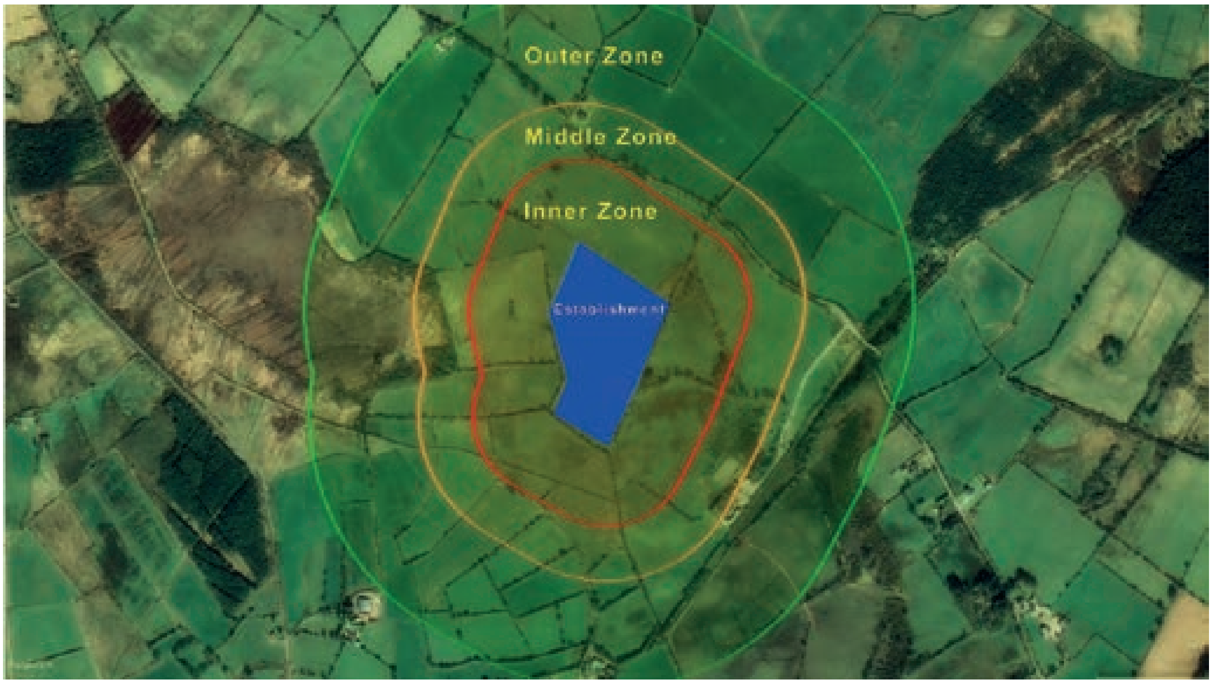


Figure 9: Generic map provided to planning authority

A planning application is subsequently received by the planning authority for a small residential development in the vicinity of the establishment.

The proposed development consists of eight residential units, designed for independent living for older people.

Looking up the generic technical advice provided by the competent authority in map form, the planning authority determines that the development lies in the centre of the middle zone.

Figure 10: Location of proposed development

Appendix 4

Interpreting the generic advice

To determine suitable development types for the middle zone, the planner looks up Appendices 2 and 3 of the Guidance on technical land-use planning

Starting with Appendix 3, which lists the suitable developments in each zone, it is noted that the first item under Middle Zone (Zone 2) development seems appropriate:

> *Developments up to and including 30 dwelling units and at a density of no more than 40 per hectare.*

Examples are also given in the same appendix:

> *Houses, apartments, retirement flats/bungalows, residential caravans, mobile homes.*

The area of the development is 2800 m². Eight units in an area of 2800 m² is equivalent to 28.6 per hectare. Therefore, as it is at a density fewer than 40 per hectare, the technical advice is 'not against', and the planner proceeds on that basis.

If the application had been for 12 units on the same footprint, then it can be noted that it would be advised against in the Middle Zone (Zone 2), since the density is greater than 40 per hectare.

Residential density greater than the threshold of 40 units per hectare is an exception and exceptions usually move to the next most restrictive level, which is Level 3.

By consulting the Level 3 developments in Appendix 3, the planner can locate the following as the second item in the table:

> *Any developments (for more than 2 dwelling units) at a density of more than 40 dwelling units per hectare.*

Level 3 developments are not recommended in the middle zone (Figure 10, Table 4). Therefore, the technical advice to the planner, to be factored into their consideration and decision, is against development at this density in the proposed location.

The planner could also have looked up Appendix 2 and identified housing as Sensitivity Level 2. Sensitivity Level 2 is permitted in the middle zone. It also identifies development at high density (> 40 per hectare) as Level 3.

There would be no requirement to formally consult with the CCA in this case because the generic advice provided is sufficient.

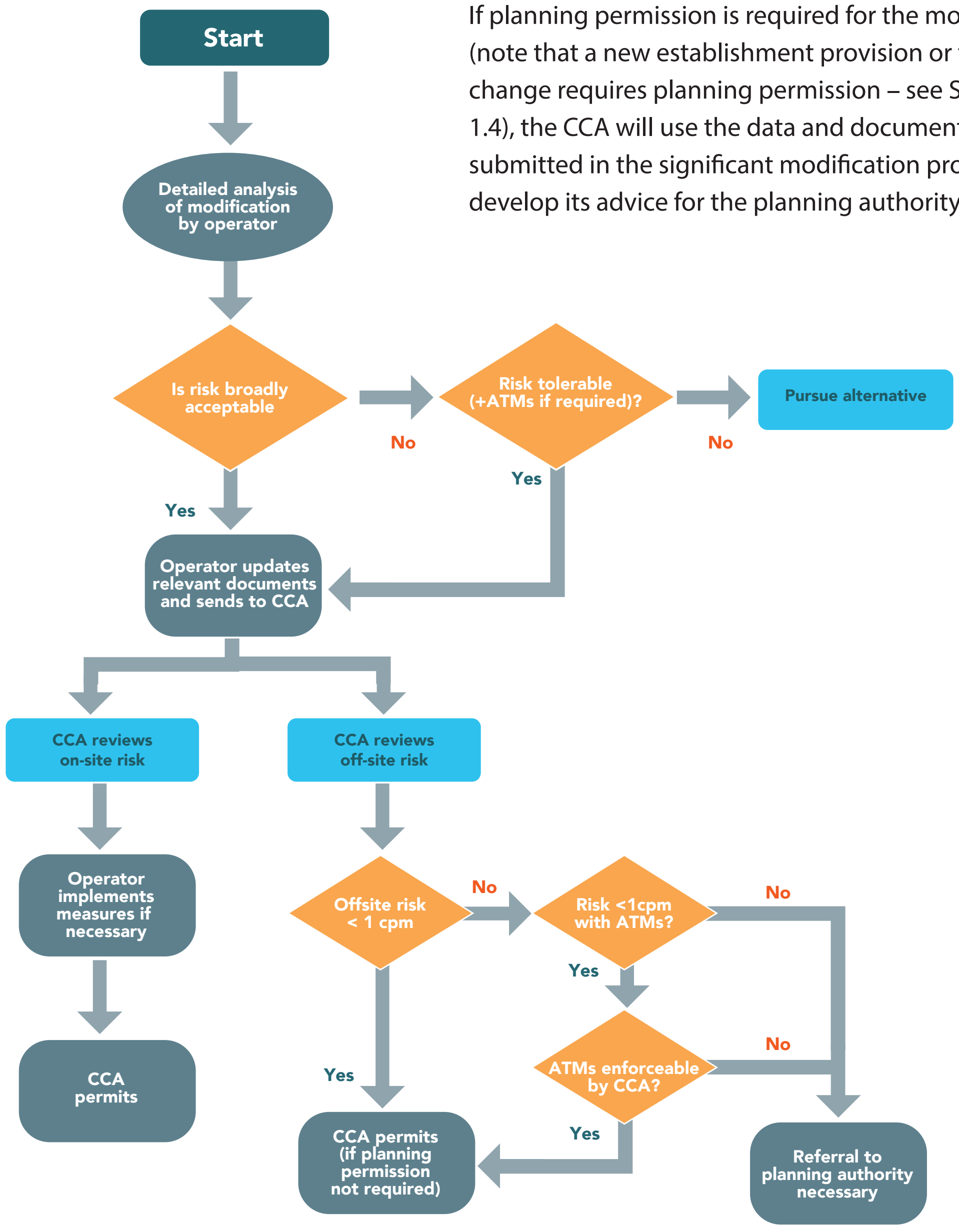
Appendix 5

Significant modifications and TLUP

An operator planning significant modification must notify the CCA in advance. The simplified chart shown in Figure 11 (adapted from a chart in the *Guidance on 'Significant Modifications' Under the COMAH Regulations)* provides an overview of the process.

Figure 11: Significant modifications and TLUP

If planning permission is required for the modification (note that a new establishment provision or tier-change requires planning permission – see Section 1.4), the CCA will use the data and documentation submitted in the significant modification process to develop its advice for the planning authority.



"ATM's" refers to additional technical measures

Notes

Further Information and Guidance:

Visit our website at **www.hsa.ie**, telephone our contact centre on **0818 289 389** or email **contactus@hsa.ie**

Use BeSMART, our free online risk assessment tool at **www.besmart.ie**

Check out our range of free online courses at **www.hsalearning.ie**

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