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| ONR Technical Assessment Guide  Annex 5 Other External Hazards |



ONR Technical Assessment Guide (TAG)

Annex 5 Other External Hazards

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# Introduction

1. This annex presents information for the inspector relating to specific natural and man-made external hazards considered relevant to nuclear safety on nuclear licensed and authorised sites. It applies the general principles set out in the Technical Assessment Guide (TAG) head document.

# Electromagnetic Interference

1. Electromagnetic interference (EMI) (also called radio frequency interference or RFI) is a disturbance that affects an electrical circuit due to electromagnetic radiation emitted from an external source. The disturbance may interrupt, obstruct, or otherwise degrade or limit the effective performance of the circuit. The source may be any object, artificial or natural, that carries rapidly changing electrical currents, such as:

* an electrical circuit.
* radar.
* communication systems.
* electrical storms.
* or from an extra-terrestrial source, typically the Sun – Part 3 of this annex covers space weather.

1. The potential for EMI to affect instrumentation and control equipment should be considered. Sources of EMI originating on the site are considered as internal hazards. Guidance on the assessment of EMI is set out in T/AST/015 on electromagnetic compatibility [1], which also includes references and sources of further information. Depending on whether the hazard can be adequately controlled, the licensee may need to provide screening to protect equipment from EMI or install instrumentation and control equipment of a proven electromagnetic compatibility.
2. Sources of EMI local to the site should be identified and characterised. External sources of EMI may vary in power with time and may be manually controlled and directional. These variations should be considered when characterising the EMI external hazard.
3. Transitory sources of EMI should also be identified, such as those used by neighbouring facilities for limited durations or those which could be reasonably anticipated to pass close to the site.
4. Sites should demonstrate a comprehensive analysis of the existing and foreseeable sources of EMI for the location. This should include local transitory sources from existing neighbouring facilities and mobile sources which could pass through the area and place an altered EMI load on the facility structures, systems and components (SSC). To achieve this analysis an extrapolation of the measured EMI load on the site will not be sufficient to determine potential sources which vary with time.
5. Where external sources of EMI have been identified for a site, the inspector should engage with the Electrical, Control & Instrumentation Engineering Specialism. Where the licensee has considered the practicability of additional equipment protection this should be considered jointly between the External Hazards (EH) and Electrical, Control & Instrumentation Engineering Specialisms.

# Space Weather

1. Space weather describes changing environmental conditions in near-Earth space. Magnetic fields, radiation, particles and matter, which have been ejected from the Sun or other stars, can interact with the Earth’s upper atmosphere and surrounding magnetic field to produce a variety of effects. Space weather can influence the performance and reliability of space based and ground based technological systems. The Sun is the dominant source of space weather which can have an impact on the Earth.
2. Space weather events have always occurred, but our modern reliance on technology driven systems makes us more susceptible to the impacts.
3. Space weather has been identified as a threat to infrastructure nationally. It is monitored as part of the UK natural hazards partnership, with the UK Met Office being the lead agency. Space weather is also considered in the USA, with National Oceanic And Atmospheric Administration (NOAA) being the lead agency. The threat to UK and USA infrastructure from space weather has been studied in order to advise policy [2], [3], [4], [5]. Nuclear facilities are not specifically identified, but the vulnerability of electric grid and other infrastructure is highlighted.
4. The major impacts of a severe space weather event can be divided into two areas - impacts on technology on Earth and threats to equipment and health in space and at high altitude [6]. They include:

* Power grid outages.
* Disruption to Global Navigation Satellite Systems (GNSS) / Global Positioning Satellites (GPS).
* High Frequency (HF) radio communications outages.
* Satellite damage.
* Increased radiation levels at high altitude.

1. Some of these have implications for nuclear safety related SSCs and operations.
2. This appendix part is focused on the hazard potential for nuclear facilities associated with space weather.

## Solar Storms

1. Solar storms are a particular aspect of space weather associated with the sudden brightening of solar active regions known as sunspots and may be characterised in terms of three phenomena: solar flares, solar energetic particles and coronal mass ejections.
2. A solar flare is characterised as a sudden release of energy from the Sun in the form of X-rays, extreme UV rays and gamma-rays which take about 8 minutes to reach Earth (speed of light) and persist in a timeframe of minutes to hours. A solar flare may also be the precursor for the ejection of solar energetic particles (SEP) and subsequent coronal mass ejections (CME).
3. A CME is the ejection of electrical plasma and magnetic fields from the solar corona as a plasma ‘bubble’ into interplanetary space. If the material is directed towards the Earth, then the event may result in a disturbance to the Earth's magnetic field and ionosphere. CMEs interact with the Earth’s geomagnetic field, with the impact accentuated when the magnetic field of the CME is oppositely aligned to the direction of the geomagnetic field. In such a configuration, CME energy and plasma is efficiently directed into the Earth’s environment, including the radiation belts, ionosphere, atmosphere and ground.
4. Solar flares are the sudden releases of energy across the entire electromagnetic spectrum. They are hard to predict, and the energy can be detected in Earth's atmosphere as soon as 8.5 minutes after the occurrence of a solar flare. An eruption event will typically take one to four days to reach Earth and persist for one to two days.
5. SEPs are highly energetic solar particles (protons and ions) travelling at relativistic speeds which may take the order of 15 minutes to 24 hrs to reach earth and persist for several days. A particle cascade can be created by solar particles at high energies interacting with the upper atmosphere. The particle cascade can be composed of neutrons, protons, muons, pi-mesons, gamma rays and electrons. These particles are typically observed at high elevation in satellite and aviation systems but also have the potential to create ground-level particle fluxes of neutrons and muons. These events are referred to as ground level events (GLE).

## Space weather impact at ground level: GIC

1. The interaction between an appropriately magnetically aligned CME or fast stream of solar wind and the geomagnetic field induces a secondary magnetic field and a surface electric field in the Earth. The consequence of this electric (‘telluric’) field is a geomagnetically induced current (GIC), which can enter any ground-based network through the earthing points.
2. Given the physical dimensions of CMEs and the geomagnetic field (both many Earth diameters wide), the impact of space weather is generally global in extent, though it is stronger towards both poles where the geomagnetic field is more readily magnetically connected to the solar wind. However regional (few hundred km to continental scale) impacts do occur, with impacts stronger on the night side of the Earth.
3. Ground level infrastructure affected by GIC includes electrical power transmission systems, pipelines and railways. These systems are affected by the GIC due to their large span. The earthing arrangements of transformers and other equipment at either ends of long transmission lines can result in a pseudo-DC current flowing through the equipment and along the lines. Depending on the design of the equipment, this current can result in saturation of the magnetic core. Assessments should consider the potential for this to result in transformer failure and premature ageing due to localised heating within the core, harmonic distortion of the voltage waveform which may cause maloperation of protection relays and other electronically controlled devices.

## Space weather impact at ground level: GLE

1. Space weather affects man-made satellites and the aviation industry. The electronics within man-made satellites can be disrupted by the particle flux, giving the potential for reducing the reliability of signals and data. This includes man-made satellites providing Global Navigation Satellite Systems (GNSS)[[1]](#footnote-2) . Where ground level infrastructure also relies on GNSS (position and/or timing), satellite communications, mobile or high frequency (HF) communications, or contain electronic hardware sensitive to ionising radiation, then there are additional space weather risks [3], [7].
2. GLE are relevant to control and instrumentation systems, with certain materials being particularly susceptible to particle fluxes creating false signals. The Electrical, Control and Instrumentation Specialism should be consulted to identify if safety claimed C&I equipment is vulnerable to ground level effects.

Space weather phenomena and associated impacts

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| --- | --- | --- | --- |
| Storm Type | Travel time | Physical Impact | Technological Impact |
| Geo-magnetic | 18-96h | Geomagnetic induced currents  increased ionisation in ionosphere  heating in the thermosphere | Power grid outages, etc  GNSS, HF comms  Satellite and other hardware damage (e.g. surface charging)  Satellite orbits (drag, collision risk)  HF comms |
| Charged particles | 10mins – 1 day | increased radiation levels  damage to sensitive electronics  increased ionisation in ionosphere | Radiation health hazard (astronauts, aircrew)  Satellite heating and instrument noise, avionics, digital chips  as above - HF comms out for up to few days in polar regions |
| Solar flares | 8mins | HF radio signal interference  heating in the thermosphere | HF comms (~mins-hrs, sunlit side)  As above. |

## Forecasting

1. The Met Office provides forecasts and warnings of space weather for Government and responder communities, critical national infrastructure providers and the public. This based on solar observations and space-based instrumentation.
2. Warning and detection systems are in place for space weather. Space based instruments in orbit between Earth and the Sun can detect CME and provide a 15 to 60 minute warning, depending on the speed of the CME. Terrestrial monitoring systems are also in place in the form of the INTERMAGNET network. These provide monitoring for geomagnetic storms and GIC.
3. Due to the near relativistic speed of SEP, there is little scope for the development of warning systems against GLE. As noted above, there may be only a few minutes delay between the observation of a significant solar flare and the first arrival of SEP at Earth.

## Characterisation

1. The UK National Risk Register [8] classes severe space weather as a highly unlikely (a probability of between 5% and 25% during the next 5 years[[2]](#footnote-3)) but potentially significant impact event. There are continuous ground-level geomagnetic records, dating back some 170 years, to substantiate the impact of space weather, as well as evidence from space-based measurements of solar activity for the last 50 years. The sunspot record itself dates back 400 years and provides some broader indication of past solar behaviour. Work is ongoing to try to establish a longer record of solar activity from isotopic analysis of polar ice cores; there is not wide consensus on the validity of the methodology.
2. As part of the UK preparedness for space weather events, a single hypothetical event was modelled and the consequences for UK infrastructure and industry estimated [5].
3. The “Carrington Event” of 1859, which has become a benchmark for extreme space weather events, has been extensively studied. Of particular note are: the fast travel time of the CME (17.6 hours to Earth from first observation of a related solar flare at the Sun by Carrington); observation of the Aurora Borealis at low latitudes and mis-operation and fires in telegraph systems. The latter impact is particularly relevant as a benchmark for the potential effects of a Carrington-like event today on electrically grounded infrastructures. Telegraph systems of the time used batteries, and operators found that the system could work without the batteries, ‘powered by the aurora’, as GIC flowed to and from the ground into the network due to the enhanced surface electric field driven by the storm. The Carrington Event has been used to estimate the frequency of extreme events, but as a single event the results are very dependent upon methodology and do not have a consensus in the scientific community.
4. The characterisation of GLEs is difficult as they have only been detectable since the mid-20th century, e.g. no GLE data is available for the Carrington Event. Frequency and severity are therefore difficult to determine.
5. Since the publication of a report by the Royal Academy of Engineering [3], which estimated that a solar storm having magnitude similar to the Carrington event is thought to have a return period of around 100 years, the nuclear industry, supported CINIF (Control & Instrumentation Nuclear Industry Forum) has undertaken research to characterise the potential hazard posed by severe space weather. Work carried out by the National Physical Laboratory (NPL) estimated neutron fluxes at ground level corresponding to return periods of 100, 1000, and 10,000 years. The work is however supported by little actual data, so there is insufficient information for these fluxes to be used to design engineered protection. However, the flux magnitudes at return periods of 1000 years - 10,000 years are such that the hazard posed by SEP cannot be ignored.
6. Using the flux estimates established by NPL, the nuclear industry undertook further work through CINIF to consider the effects of neutron irradiation on the electronic components used within ground-level control and instrumentation electronics in the nuclear industry. Radiation effects in general were reviewed but the major focus was on single event effects (SEE) whereby individual particles of ionising radiation can trigger soft, firm or hard failures in modern microelectronics. In the absence of mitigating factors such as shielding and de-rating, certain microelectronic technologies will suffer significant effects in the case of extreme GLEs. Older equipment incorporating similar component families is also a concern, since SEE vulnerability dates back thirty years or more. Conversely, certain other technologies such as the simpler forms of flash memory appear considerably more robust based on current evidence and would thus suffer minimal impact.
7. Due to the uncertainties associated with space weather and the immaturity of an engineered response, it is difficult to protect SSCs against space weather. Lessons can be learnt from systems which are subject to harsher space weather environments, including aircraft and satellite systems. Satellites are currently designed to withstand or detect and react to space weather. The particle and magnetic fluxes experienced by satellites is clearly much larger than that for ground based systems. It is therefore not expected that ground-based systems should necessarily replicate the engineering solutions such as multiple detectors used in these systems, but this example does illustrate that engineered protection against space weather has matured in other industries.
8. Research is ongoing to consider suitable mitigation strategies such as the use of less vulnerable components, operating high voltage devices below rated values, shielding, error detection/correction and radiation alert monitoring to reduce the likelihood of inappropriate reaction to system anomalies.

## Hazard combinations

1. Space weather EH analysis should consider the combined and consequential hazards and faults and the multiple ground-level phenomena from a space weather event.
2. For example, a significant GIC is generally considered to be a frequent event, and is likely to result in Loss of Offsite Power (LOOP). Whilst LOOP (without a solar storm) is covered in nuclear safety cases as a frequent event, the combined effect of LOOP and GIC and GLE should be considered. Depending on the severity of the solar storm, offsite power may be unavailable for some time due to the potential for damage to transformers within the off-site power supply network, and there is likely to be concurrent disruption to communications and transport networks. Furthermore, damage to microelectronic systems may be expected for severe solar storms.

## ONR expectations

### Hazard Definition

1. The licensee should define design basis space weather events for phenomena which could affect nuclear safety on the site. This includes GIC and GLE. The definitions should include magnitude and duration.
2. The uncertainties associated with the science of space weather means that the derivation of a design basis event in accordance with SAP EHA.4 may not result in a useable definition. The large uncertainties and short instrumental record in the underlying data may dominate when defining design basis events.
3. A substantiated representative event may be a better approach to understanding the nuclear safety implications of space weather than a statistical derivation. The design basis event should not be less onerous than that used for other ground-based engineered infrastructure.
4. The definition of GIC should include the duration of the peak event as well as the magnitude. Transformer overheating may be more likely for a longer event. This may include sensitivity studies on the duration assumptions. The wider grid response to a space weather event could affect the impacts on a licensed site, this can be better understood through the grid standards. Widespread grid disruption could cause a loss of off-site power (LOOP) irrespective of the local response to the event. A local specification for transformer resistance to space weather may be disproportionate if it is resilient to an event which, through the grid standards, the wider network will be significantly damaged by.

### Engineering Substantiation

1. It is acknowledged that the science of space weather as an EH is immature in terms of the event and the engineered response. It is therefore not possible to identify detailed relevant good practice (RGP). The expectations for duty holders’ substantiation against space weather are therefore different to those of more mature EHs. This does not alter requirements of the SAPs for EHs to be identified and the vulnerability of SSCs to be assessed. Licensees should look to identify the potential effects of space weather on nuclear safety.
2. Inspectors should expect licensees to have considered the implications of the latest research as outlined above and to have developed an appropriate protection strategy. The strategy should identify:

* whether there are any vulnerable components.
* what the impact is on nuclear safety.
* any practicable mitigation or protection measures.

1. The strategy should take into account the level of uncertainty associated with the hazard characterisation and its effect on components in order to ensure a proportionate and balanced response to space weather hazard. The strategy should be updated as more information becomes available.

### Inter-Disciplinary Working

1. The consideration of nuclear safety risk due to space weather requires inter-disciplinary working between the ONR external hazards inspector and electrical control and instrumentation specialist inspectors. The vulnerability to space weather events of the safety related SSCs will depend on the technologies used and the interfaces between systems.

# Biological Hazards

1. Biological hazards cover a wide range of potential issues. There is no SAP that refers specifically to biological hazards; however, they should be considered as part of the general need to cover all credible hazards (EHA.1) [9].
2. Typical hazards that need to be considered are as follows.

* Marine
  + Jellyfish.
  + Seaweed.
  + Fish.
* Land
  + Infestation from mice, rats, rabbits etc.
  + Biological debris such as fallen leaves.
* Air
  + Swarms of insects / birds.

1. Marine hazards can create a blockage or flow restriction on the intakes for sea or river cooling water systems. This has led to reactor trips and must therefore be considered as a fault. In some cases, severe damage to drum screens has ensued, and material has passed into the seaward side of coolers within the plant itself. This has led in a number of cases to reactor trips. Where there is a high reliance on cooling systems that have secondary cooling from river or sea, the sensitivity of the plant to interruptions of supply should be well understood.
2. There are some techniques such as sonar and bubble curtains that can limit or deter the influx of marine creatures. However, against organisms that can be dispersed and spread (such as seaweed through wave action for example) it is preferable to rely on more physical means to prevent ingress.
3. Some marine organisms are able to pass through filter systems in suspension in the early stages of their lifecycle, but could present a hazard if they were to grow inside the facility. Material selection and chemical dosing can be used to reduce the build-up of marine life which can pass through filters and grow after attaching to the surface of systems carrying cooling water. Such build-up can cause flow restrictions by narrowing pipes or cause blockages if they break off and block pipes further in the system. Periods of stagnation or draining present a greater risk of such blockages as the marine life may build up or die and therefore be more vulnerable to entering the system upon recommissioning of the system. Decomposing organic mater also has the potential to create hazardous or explosive atmospheres.
4. Infestation of mice etc is primarily prevented through the use of high quality doors and sealing arrangements to buildings and service trenches etc, and by management arrangements to deter animals from entering buildings. Pest control measures may also be used on the wider site. The presence of vermin increases the risk of damage to insulation to electrical and mechanical systems, and illness to workers encountering organic pathogens (e.g. leptospirosis and Psittacosis) during their work.
5. Insect swarms can pose a threat to intakes, to heating, ventilation and air conditioning or back-up diesel plant by restricting air flow and limiting their operability. It is therefore useful to ensure that this hazard is considered as part of the design, and suitable mitigation measures are in place.
6. Fallen leaves and similar debris can block building gutters, drains and gullies, especially in autumn or after severe storms. Protection is normally provided by routine inspection/maintenance activities to ensure drainage systems remain operational. On some sites, measures to manage vegetation may also be required.
7. It is common to find a high reliance on operator intervention either to prevent any biological hazard from developing unduly, or in recovery of the situation. It is therefore recommended that an inspection of operating instructions and training are undertaken as part of a review of these hazards. Particular attention should be paid to higher risk times, such as changes to the plant configuration or operation, and seasonal increases in the prevalence of the biological hazard. Plant operation and commissioning instructions should provide confidence in the absence of unrevealed clogging material.

# Industrial Hazards

1. These hazards arise either due to the conveyance of hazardous materials on adjacent transport routes (e.g. pipeline, rail, road and sea) or adjacent permanent facilities (e.g. nuclear facilities, quarries, tank farms, etc.). Typical hazards that can arise from industrial plants may be from: stored gas, fuel, explosives, pressure vessels, radiological release or turbine disintegration. Useful data and references are available on some of these aspects in a variety of licensee-specific documents, in particular, the reactor licensees have developed a comprehensive methodology for assessing missile damage. EHs analyses should consider all potential sources of external missiles and explosion.

## Explosion / missiles

1. Inspectors may wish to gain confidence that, where appropriate, the following have been considered:

* Sources of possible explosions / missiles should be identified, the possible magnitude of explosions, blast waves and the likely size, (pressure and impulse, including thermal reflection effects), ground effects, frequency and trajectory of missiles estimated, and their effects on safety-related plant and structures assessed. Note: stores of fuel or chemicals within the site boundary should be dealt with as internal hazards but may be susceptible to EH initiators.
* The results of a hazard analysis in conjunction with the licensee’s acceptance criteria should be used to verify the adequacy of protection provided by spatial segregation, protective barriers, and redundancy in safety-related plant and safety systems.
* Possible causes of explosions to be considered include the ignition of flammable gas, vapour or oil-mist clouds, boiling liquid expanding vapor explosion (BLEVE), exothermic reactions, pyrophoric materials, failure of pressure parts, and explosions associated with switchgear, high-energy transformers, electrical batteries, terminal boxes and power cables. Also leaks from underground gas supplies, or other sources, that could (if heavier than air) accumulate in building basements and drains.
* Consequential effects should also be considered, ie domino effects following fire / explosion and generation of secondary fragments.
* Where high reliance on containment is required, particular attention to the effects of missiles should be given. Special consideration should be given to containment structures with fragile structural elements, e.g. roofs.
* Examples of industrial facilities examined for their potential threats to nuclear facilities include:
  + Refineries.
  + Hydrogen generation plants
  + Liquid petroleum gas pipelines.
  + Wind turbines.
  + Explosive-handling facilities.
  + Dockyards.

## Toxic, corrosive and cryogenic materials and gases

1. Inspectors may wish to gain confidence that, where appropriate, the following have been considered:

* Toxic, corrosive and cryogenic materials and gases have the potential to disable both personnel and safety-related plant. The safety case should provide a demonstration that the range of materials that if released could either disable, impair or cause the asphyxiation of personnel, or may disable safety-related plant and equipment have been identified and risk reduced SFAIRP.

## Hazards from adjacent nuclear sites

1. Adjacent or nearby nuclear sites have the potential under accident conditions to release nuclear and other types of radioactive materials that could affect the site being assessed. This is in addition to the conventional industrial hazards that might arise, such as missiles from turbine disintegration and hazardous gas release (e.g. carbon dioxide). Also, EHs affecting the site being assessed have the potential to affect nearby nuclear sites through the common cause effect.
2. It is likely that any hazard arising from an adjacent nuclear site would prompt the implementation of emergency arrangements on that site and, if severe enough, invoke the off-site emergency plan. In both cases, the response of the site being assessed will likely be governed by its own emergency arrangements and its contribution to the local authority off-site plan. EHs inspectors may assure themselves that provision has been made in the site’s emergency arrangements to accommodate the effects of EHs on nearby nuclear sites. Special consideration of the protective measures will be required where the radiological threat from a neighbouring site is significantly different in magnitude or isotopes to that from the licensed site (e.g. a waste storage site next to a nuclear power plant).

## Other considerations

1. A number of situations can arise that may provide the potential either directly or indirectly, to create hazards. For example:

* Tenants may exist on a licensed site, whose operations are not under the direct control of the licensee. In such cases the tenancy arrangements with the licensee should positively identify the potential hazards arising from the tenant’s activities.
* Third party activities may take place near the licensed site that could affect the effectiveness of safety related SSCs e.g., sea defences, or the potential for transport accidents.

# Landscape Change

1. Landscape change is not a particular EH itself. However, the processes that drive it are clearly related to EHs. The processes themselves may well be gradual in nature, (although significant change could arise from a single EH event such as a severe storm winds or strong wave action impacting on the local coastline). However, over time they may undermine the protection against the more extreme design basis and beyond design basis events.
2. The key processes involved are:

* Wind induced erosion.
* Water induced erosion / ground movement.

1. Other effects such as glacial rebound are of minimal practical interest for the 100-year timeframe generally under consideration, but may be considered as a compounding effect with climate change on sea level rise.
2. The more detailed effects that result from the above are listed below:

* Wind (aeolian) induced
  + Wind-blown sand and dune movement.
* Water induced
  + Coastal erosion.
  + Longshore drift.
  + Shingle mounding or erosion.
  + Sediment deposition or erosion.
  + Water-course erosion.
  + Water-course path change.
  + Water-table movements resulting in settlement / heave.

1. The gradual nature of these processes means that, in most case, a monitoring regime (by inspection) is appropriate to ensure that significant changes are identified in a timely manner, so that management actions can be implemented to prevent or mitigate the effects of landscape change hazards. Inspectors may gain confidence that the monitoring system is appropriate, such that after a storm surge event, there is a requirement to inspect those areas of sea defence that may have been damaged, and to have arrangements in place to ensure that repairs can be undertaken in a suitable timeframe. Clearly, this should be linked to any weather warning arrangements that may be in place. Note that inspection of off-shore intakes and outfalls can be problematic, but these element must not be overlooked if they contribute to the safety of a facility.
2. The licensee should consider the potential for storms to cause significant changes to on-shore landscape or near-shore bathymetry. The sensitivity of flood modelling to assumptions on these features should be understood. The potential for repeat storms to impact on significantly altered local features should be considered in the flooding modelling and response.

# External Hazards Resulting From Naturally And Anthropogenically Occurring Gases

1. Naturally and anthropogenically occurring ground gases that could present a threat to nuclear and conventional safety can be generated by the natural lithology of a nuclear installation site, putrescible constituents of made ground and the degradation of organic materials and contaminants in soils and / or groundwater. Ground gases of concern typically comprise carbon dioxide (an asphyxiant) and methane (explosive), though in some cases other gases such as hydrogen sulphide or carbon monoxide (poisons) or radon (radioactive) could be present.
2. The risk of naturally occurring gases should be determined at the siting stage of a nuclear facility, including new sites and new facilities on an existing site. The suitability of a site is covered by SAP ST.4 [9] which requires that the suitability of the site to support safe nuclear operations should be assessed prior to granting a new site licence. The risk should be identified and evaluated according to the significance for the safe operation of the nuclear installation and any important natural phenomena that could lead to potential hazards should be investigated.
3. The possibility of generation of naturally occurring gases should be considered during site characterisation and geotechnical and hydrogeological investigation. While this will principally be a civil engineering activity, EHs inspectors should view this as a cross cutting activity that may also involve liaison with internal hazards.
4. The following are common natural and anthropogenic sources of gas and their typical products:

* Peat bogs and moss lands (methane, carbon dioxide).
* Uranium and thorium bearing rocks such as granites (radon).
* Carbonate rocks such as limestone and chalk (carbon dioxide).
* Organic rich rocks such as coal measures (methane, carbon dioxide, carbon monoxide, hydrogen sulphide).
* Marine, river and lake sediments (methane, carbon dioxide, hydrogen sulphide).
* Made ground (consisting of natural or man-made materials) (methane, carbon dioxide, hydrogen sulphide, volatile organic compounds and others).
* Farmland (methane, carbon dioxide, hydrogen sulphide).
* Sewers (methane, carbon dioxide, hydrogen sulphide).

1. In order to prevent the collection of gases that could pose a threat to the health and safety of personnel, limit access to areas that could affect nuclear safety or prevent operators from carrying out safety related tasks, civil engineering design. SAP ECE.11 states that “The design should take account of the possible presence of naturally occurring explosive, asphyxiant or toxic gases or vapours in underground structures such as tunnels, trenches and basements”. Plant areas such as cooling water intake tunnels, drum screens and forebays may allow the collection of organic material (e.g. seaweed and jellyfish) that could decompose with the risk of gas generation and gas may be dissolved in water.
2. A list of useful references relating to guidance, standards and risk assessment of naturally occurring gases is given at [10]. Civil engineering advice is available in NS-TAST-GD-017 [11].

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# Glossary and Abbreviations

BLEVE boiling liquid expanding vapor explosion

CINIF Control & Instrumentation Nuclear Industry Forum

CME coronal mass ejections

EH External Hazards

EMI electromagnetic interference

GIC geomagnetically induced current

GLE ground level events

HF high frequency

IAEA International Atomic Energy Agency

LOOP Loss of Offsite Power

NPL National Physical Laboratory

RGP relevant good practice

SAP Safety Assessment Principle(s)

SEE single event effects

SEP solar energetic particles

SSC structures, systems and components

TAG Technical Assessment Guide(s)

WENRA Western European Nuclear Regulators’ Association

1. Often referred to as Global Positioning System (GPS), although this is one of a series of systems. [↑](#footnote-ref-2)
2. The difference in expectation of hazard return frequency between the UK national risk register and the SAPs should be noted when qualifying language such as “highly unlikely” is used instead of numerical values. [↑](#footnote-ref-3)