Programme Area: Nuclear

Project: Natural Hazards Review

Title: Annexe to main report documenting hazards in tabluar form

Abstract:

This large spreadsheet contains the details regarding each hazard and associated methodology and how it was assessed in phase 1. This spreadsheet is the repository of detailed knowledge from phase 1. It is included as a print as an appendix to the main report, but it is provided separately in its own right to aid its use and understanding.

Context:

The Natural Hazards Review project will develop a framework and best practice approach to characterise natural hazards and seek to improve methodologies where current approaches are inefficient. This is to improve energy system infrastructure design and the project is intended to share knowledge of natural hazards across sectors. The project will be completed in three stages. Phase one will focus on a gap analysis. Phase two will look at developing a series of improved methodologies from the gaps identified in phase one, and phase three will demonstrate how to apply these methodologies. Finally, phase 3 will develop a “how to” guide for use by project engineers.

Class	Hazard	Parners with skills						Available Mature Methodologies	Expert judgements on available methodologies, including associated uncertainties, credibility limits	Climate change impacts	Uncertainties on climate change impacts	potential consequences and return level by sectors							Existing Guidelines and regulatory frameworks impacting the UK	Example of industrial application	trends in R&D	Identified gaps	Prioritisation and justification why the gaps should be addressed
		EDF Energy R&D UK Centre	EDF Nuclear Generation	Nuclear New Build	Met Office	Mott MacDonald	AIR Worldwide					Nuclear	Hydropower	Transmission & distribution	Insurance	Thermal Generation	Oil and Gas	Renewable					
A-Meteorological Hazard	*Extreme Rainfall*	x	x	x	x	x	x	(1) PMP (Probable Maximum Precipitation); Regional Analysis Pooling and Intensity duration curves method [32]; (2) Stationary EVA; (3) Coupled Global Circulation Model with Meoscale Numerical Weather Prediction Models [19], (4) Monte Carlo Approaches [33]	(1) PMP: Mature methodology, large subjectivity, large uncertainties, usually associated with the 10-4 annual frequency event; (2) EVA: Mature methodology, not adapted for high resolution rainfall, does not use physical knowledge, huge uncertainties due to the small amount of data at the local scale, need to allow for different characteristics of site location compared to weather station location	Possible increase in extreme rainfall since a warmer climate holds more water. Increase in frequency (Tab IV-1 IAEA), increase in annual maxima and decrease in return period [15]	Very uncertain, may change regionally, natural variability makes it hard to predict [14], influenced by seasons and North Atlantic Oscillation [15], Not currently enough data to estimate degree of impact especially regarding frequency	flooding of the platform, 10-4	dam safety due to flooding	x	All property lines of business can be effected by extreme rainfall although damage tends to be restricted to ground floors and basements	flooding of the platform			The Flood estimation Handbook [32]; Flood Risk statement, IH124; Models require validation for use in Solvency II and Lloyds synidcates must report exposure in relation to Realistic Disaster Scenarios, IAEA**, Planning Policy Statament 25 (PPS25), BS EN 752, BS 12056BS EN 50341, BS 61936, BS 7671, Sewers for Adoption, CIRIA guides, National Grid Techical Specifications	Nuclear: Met Office reports for EDF Energy, Established Flood Risk Assessment techniques across NG fleet, Flood estimation Handbook used to for roof drainage project for Hartlepool and Heysham power stations.	Stochastic Modelling [34], Weather type approaches [33]	Very few observation available for high resolution rainfall (15 minutes), available methods not adapted, new R&D needed .	Short duration extreme rainfall estimation are critical in urban hydrology, drainage system design and they can cause flash flood. They cause huge damages. Pluvial flooding can be more damaging than fluvial
A-Meteorological Hazard	*Frazil*		x		x	x		(1) Finite Element Analysis; (2) Comptuational Methods for Ice Flow Simulation (Kallen-Brown, J., 2011) [26]; (3) EVA on low temperature	Methodology (2) provides a means of modelling ice flows taking density variations into account.	Possible increase [17]; Decrease in ice duration and seasonal ice cover [22]	Uncertain due to limited available data [22]	clogging of the heat sink	x			clogging of the heat sinks		load on pile for offshoe ind farms					
A-Meteorological Hazard	*Extreme and very rapid changes in temperature*		x		x	x				Impossible to quantify fom climate models	Impossible to quantify fom climate models	temperature-related aging of infrastructure		x			x		BS 6399, BS EN 50341, Eurocodes, National Grid Technical Specifications, API STD 520, 594, 600. 602 AND 607.	EDF NG PSR studies	Non-stationay EVA, Climate models scenarios improvement		
A-Meteorological Hazard	*High extreme ambient air temperatures*	x	x		x	x		Stationary and non-stationary EVA for air temperature (4.4 IAEA [7])	Stationary EVA (see comment given for EVA on rainfall) Non-stationary EVA can provide unrealistic projections when the trends detected on the past series are projected too far in the future	Warmer and more frequent hot days/nights over most land areas / warm spells and heat waves (Tab IV-1 IAEA); Increased average annual temperature and daily average maximum temperature [14]	Virtually certain / very likely (Tab IV-1 IAEA); Lower confidence in model capability at regional scales (IPCC AR5 [13]); 4/5 stars confidence [14]	cooling is less efficient as temperature increases		temperature increases could potentially lead to more incidences of de-rating of grid networks		may decrease performaces			EVA for air temperature(4.4 IAEA [7]), BS 6399, BS 5400, BS EN 50341, BS 61936, BS 7671; Eurocodes ; National Grid Technical Specifications	EDF NG PSR studies	Non-stationay EVA, Climate models scenarios improvement		
A-Meteorological Hazard	*Low extreme ambient air temperatures*	x	x		x	x		EVA for air temperature(4.4 IAEA [7])	Stationary EVA (see comments given for EVA on rainfall)	Decreased frequency of cold winters and cooler springs (but severe cold seasons can still occur) [14]	Lower confidence in model capability at regional scales (IPCC AR5 [13]); 3/5 stars confidence due to natural variation [14]	surge in demand leading to overload of generators and cable damage, excessive thermal contraction of overhead power lines		x					EVA for air temperature (4.4 IAEA [7]); BS 6399, BS 61936, BS 7671 BS 5400, BS EN 50341; Eurocodes ; National Grid Technical Specifications	EDF NG PSR studies			
A-Meteorological Hazard	*Extreme high water temperature*	x	x		x	x		Stationary and non-stationary EVA	Stationary EVA (see comments given for EVA on rainfall) Non-stationary EVA can provide unrealistic extrapolation when the trends detected on the past series are extrapolated to the future	Projected increase in global mean temperatures [23]	Not regionally uniform [23]	water intake - cooling is less efficient as temperature increase								Established Flood Risk Assessment techniques across NG fleet			
A-Meteorological Hazard	*Extreme low water temperature*	x			x			Stationary EVA with due account of salinity	Recent reports cannot confidently fix a value for extreme low sea temperature. Only an upper bound 10-4p.a. value can be provided.	Climate change projected to warm the sea temperature in future (but cold sea temperatures could still occur) [12]	Changes in transport currents may result in local cooling even if the global mean heat content is rising (IPCC AR5)	frazil ice and clogging of the heat sink								Nuclear studies for NPP in France and UK		A more precise judgement on the lowest value should be sought	
A-Meteorological Hazard	*Extreme snow (including sticking snow, snow avalanches, icing, hard rime)*	x	x	x	x	x		(1)Stationary EVA for snow pack (4.4 IAEA [7]); (2) Numerical Weather Prediction Models, (3) eurocodes	Stationary EVA (see comments given for EVA on rainfall)	Climate change projected to warm the air temperature in future, but severe cold spells with the risk of snow could still occur [12]	Insufficient timeseries of data to be able to identify trends rather than natural variability	load on buildings		ice on power lines (noticeable problem in the U.S.)	all insurable property lines of business can be effected by extreme snow	x		load on blame of offshore wind farms	EVA for snow pack (4.4 IAEA [7]); British Standards: BS6399-3 (now withdrawn), BS EN 1991-1-3; Eurocodes, BSI Codes, Models require validation for use in Solvency II, National Grid Technical Specification, EN 50341, BS7354, CP 3, ONR Safety Assessment Principles	EDF NG Commissioned Studies with Met Office, Hazard Safety Cases, Periodic Safety Reviews, resilience/ defence in depth, and the continual management of the overall commercial and nuclear safety risk.	Modelling moving towards numerical due to greater computing power; The effect of combined hazard	Some uncertainty around atmospheric physics and formation of frozen precipitation; Medium priority Existing safety cases are based on the consequences of failure being tolerable	
A-Meteorological Hazard	*Extreme wind*	x	x	x	x	x	x	(1) Stationary EVA (Pareto, Weibull); (2) Eurocodes; (3) Probabilistic Monte-Carlo simulation approach deriving a stochiastic catalogue of parameters from scientifically adjusted historical distributions. Numerical models and climate models can also be used	(1) Huge uncertainties due to the small amount of data at the local scale, not adapted for short series, does not use physical knowledge, up to 10-2; (3) Robust methodology for characterizing hazard over an extended period of time	Potentially yes - Warmer oceans are likely to alter tropical cylone formation. Changes in atmospheric heating are likely to impact extratropical cyclone intensity and tracks, similarly they are likely to impact severe thunderstorm formation. However, there is low confidence in projected changes in storminess, [12], [14].	Very uncertain; Insufficient timeseries of data to be able to identify trends rather than natural variability	load, projectiles		winds knocking over trees which in turn damages power line	All insurable property lines of business can be effected by extreme wind	x		equipment failure on wind farms, 50y return period	OW [1,2,9], British Standards BS6399-2 (now withdrawn), BS EN 1991-1-4; Engineering Science Data Unit (ESDU) Wind Engineering Series guides, BSI Codes, Eurocodes, National Grid Technical Specification, EN 50341, BS 61936, BS 7671, IEC 61400, Models require validation for use in Solvency II and Lloyds synidcates must report exposure in relation to Realistic Disaster Scenarios, BS7354, CP 3, CP 3-2, ONR Safety Assessment Principles	Hazard Safety Cases, Periodic Safety Reviews, resilience/ defence in depth, and the continual management of the overall commercial and nuclear safety risk. EDF NG Commissioned Studies with Met Office ; AIR 400 series occupancy coding using component based damage functions	Moving to numerical/physical based modelling rather than statistical based modelling due to the increase in computer power; Regional Frequency Analysis	The effects of the North Atlantic Oscillation (NAO) and jet strength on extreme winds; The effects of climate change on extreme winds; Is there a theoretical upper limit to extreme wind speeds due to atmospheric characteristics? Investigation on the applicability of EVA results, and how to compare them with the equivalent values derived in the Eurocodes	May be included in hazard combination; High Priority:An under-estimation of extreme winds (and hence wind pressure loads) could undermine nuclear safety cases and challenge the claimed lines of protection e.g. in the event of partial collapse of buildings, loss of cladding, interaction threats, the formation of wind-blown missiles etc.
A-Meteorological Hazard	*Tornadoes*	x	x	x	x	x	x	(1) Stationary EVA (Pareto, Weibull); (2) Linear methods (observations per area etc in Met Office reports) utilised to estimate frequencies; (3) TORRO estimation of return period vs intensity (tornado inventory) based determination of the frequency of occurrence for stated levels of tornadic wind-force in particular nominated zones	(1) Huge uncertainties due to the small amount of data at the local scale, not adapted for short series, does not use physical knowledge, up to 10-3	It is currently not possible to make a link between climate change and tornado activity. Climate change may have a number of effects on atmospheric conditions that may or may not favour tornado formation, the relatively short and unreliable record of tornado activity makes it difficult to determine a definite trend in this. Climate models are currently unable to resolve small-scale phenomena such as tornadoes, and no models exist which can use climate model data to predict future	Very uncertain	load, projectiles		x			x	equipment failure on wind farms	OW [1,2,9], TORRO Guidelines, IAEA Safety Guides IEC 61400, API STD 600, Models require validation for use in Solvency II, ONR Safety Assessment Principles	Hazard Safety Cases, Periodic Safety Reviews, resilience/ defence in depth, and the continual management of the overall commercial and nuclear safety risk.	Trend towards using meteorological parameters in addition to statistical techniques. Increasing use of numerical methods for vulnerability analysis. Eg Computational fluid dynamics	Some uncertainty around formation of tornadoes; The effects of under-reporting. Due to the effects of mismatch of population between urban and countryside areas.	High Priority:An under-estimation of extreme winds (and hence wind pressure loads) could undermine nuclear safety cases and challenge the claimed lines of protection e.g. in the event of partial collapse of buildings, loss of cladding, interaction threats, the formation of wind-blown missiles etc.
A-Meteorological Hazard	*Lightning*			x	x	x	x	Estimated annual frequency of exceedance (calculating lightning strike frequency) (4.35 IAEA [7])	Strike intensity is a very uncertain measure to be used cautiously	Increase in number of lightning days [25]	Uncertainties from modelling (model convective available potential energy (CAPE) and use empirical formula to relate to flash frequency), varies across regions [25]	x		x		x	x		Estimated annual frequency of exceedance (calculating lightning strike frequency) (4.35 IAEA [7]), BS 6651, BS 62305, BS 61936, BS 7671, BS7354; IEC 61400, IEC 61400, IEC 60079; API STD 607, API RP 2003			EVA not applied to the existing data	
A-Meteorological Hazard	Hailstones				x	x	x	(1) Probabilistic Monte-Carlo simulation approach deriving a stochiastic catalogue of parameters from scientifically adjusted historical distributions; (2) Met Office work [16]	Yes, methodology produces scientifically plausible hail stone swathes for characterizing hazard over an extended period of time	Potentially yes - due to impacts on severe thunderstorm formation. However this is very uncertain and any projected trands are small, [30].	Insufficient timeseries of data to be able to identify trends rather than natural variability	x			All insurable property lines of business can be effected by hailstones although damage tends to be restricted to roofs			hail can cause significant damage if the hail is of sufficient size/quantity on wind farms	Models require validation for use in Solvency II	AIR 400 series occupancy coding using component based damage functions		Some uncertainty around atmospheric physics and formation of frozen precipitation, Emerging risks, very little knowledge	Could better quantify size distribution of hail with better understanding of physics
A-Meteorological Hazard	*Humidity (including mist and fog)*				x	x		EVA of extreme wet bulb temperature available	Do not combine the output from extreme air temperature with that of the wet bulb. Taking the extreme values from both and assuming that they could occur at the same time is not necessarily an appropriate approach	Reduced relative humidity over land (higher temperatures over land than ocean) [23], may not apply to the UK (maritime island not continental landmass)	Medium confidence that RH reductions over land are likely [23]	fog worst consequence is the zero visibility											
B-Marine Hazard	*High tide - extreme sea level - extreme sea flooding- storm surges*	x	x	x	x	x	x	(1) Stationary EVA - Direct Method; (2) JPM (Joint Probability Method); (3) Numerical model - Princeton ocean model, SLOSH, Deltares for the North Sea as examples; (4) Regional Frequency Analysis	(1), (2) see comment given for EVA on rainfall; (3) Various numerical models can represent water levels due to storm surge with good accuracy, (4) more robust than EVA	Yes, increased incidence (Tab IV-1 IAEA), Sea level rise from melting of large ice sheets and vertical land movement (UKCP09 [12]), Since the storm surge is related to the wind events, an increase in intensity/frequency of wind events could cause an increase in storm surge events	Uncertainties on the magnitude of the sea level rise (scenarios H++), Likely increased incidence (Tab IV-1 IAEA), Hard to predict regional influences (changes in ocean circulation/temperature/salinity...) (UKCP09 [12]), Impact of sea level change will automatically impact storm surge severity/impacts	flooding of the platform, 10-4		x	All insurable property lines of business can be effected by extreme sea flooding although damage tends to be restricted to ground floors and basements			Impact on offshore wind farms, 50y return period	OW [1,2,9]; Models require validation for use in Solvency II and Lloyds synidcates must report exposure in relation to Realistic Disaster Scenarios; United Kingdom Climate ImpactsProgramme, UKCIP, BS PD 8010	Established Flood Risk Assessment techniques across NG fleet - embedded into safety cases and covered under PSR; AIR 400 series occupancy coding using component based damage functions	Storm modelling coupling meteorological and hydrodynamical models; Increase in the use of Numerical modelling; Paleodata	Lack of high resolution input terrain data and computational power required to utilise high resolution data. Poor understanding of scouring of foundations and debris effects	Placement, construction and impacts of flood defenses could be better understood

B-Marine Hazard	*Wind generated waves (long or short fetch)*	x	x		x	x		(1) Stationary EVA; (2) Hydrodinamical modelling using extreme wind as input	(1) Huge uncertainties due to the small amount of data at the local scale, not adapted for short series, does not use physical knowledge, up to 10-3; (2) Depending on the methodology used for the wind estimation	Potential impact [11]	Very uncertain and linked to the wind evolution, very variable across regions and need long time series to differentiate between change and annual variability (UKCP09 [12])	flooding of the platform, 10-4				x		impact on waves energy farms, offshore wind power, 50y return period	OW [1,2,9], Nuclear [7]	Established Flood Risk Assessment techniques across NG fleet - embedded into safety cases and covered under PSR	Numerical modelling Regional Frequency Analysis (Weiss, 2015)		
B-Marine Hazard	*Tsunami*	x	x		x	x	x	Enhanced TUNAMI model used by AIR. Report on threat posed by tsunami to the UK by DEFRA [18]	Existing numerical models can be very accurate in their prediction of water levels from tsunami inundation. However, this is very dependant upon the quality and accuracy of the underlying digital terrain model/ bathymetry. Validations based on field-measured water velocities are limited in number	Yes - rising sea levels will enhance Tsunami hazard, by increasing the baseline sea water level	Uncertainties as to magnitude of sea level rises	flooding of the platform, 10-4		x			x	wind power, 50y return period	Models require validation for use in Solvency II and Lloyds synidcates must report exposure in relation to Realistic Disaster Scenarios; API ST 594	EDF NG Safety Cases and PSR; AIR 400 series occupancy coding using component based damage functions; Department for Environment, Food and Rural Affairs (DEFRA) Report: The Threat Posed By Tsunami To The UK, Study Commissioned by Defra Flood Management, 2005	Movement towards numerical simulation. Trends for 3D simulation for detailed site specific analyses; Numerical modelling; Paleodata	Very limited validation data available for inland flows and limited understanding of the forces on structures due to flow. Poor understanding of scouring of foundations and debris effects	Placement, construction and impacts of flood defenses could be better understood
B-Marine Hazard	*Extreme low sea level*	x	x		x	x		(1) stationary EVA - Direct Method; (2)JPM (Joint Probability Method)]	(1), (2) Huge uncertainties due to the small amount of data at the local scale, not adapted for short series, does not use physical knowledge, up to 10-3, not valid for sites with large tidal range			water intake acces to cooling water, 10-4						stability of the pile for offshore wind farms		Studies for NPP along France and UK shoreline			
C-Hydrological, Hydrogeological	*River flood*	x	x		x	x	x	(1) EVA, (2) Coupled Global Circulation Model with Mesoscale Numerical Weather Prediction Models [19] Hyrological and run off geenration with flood routing models (3) Statistical Stochiastic Simulation Approach	(1) Huge uncertainties due to the small amount of data at the local scale, not adapted for short series, does not use physical knowledge, up to 10-3, not valid for sites with large tidal range; (2) uncertainities on the parametrization and link between the hydrological cycle and the atmosphere	Yes, climate change could lead to more frequent and intense rainfall events. Sea level rise will affect the lower tidal reaches of rivers making fluvial flooding more likely	Uncertainties on how climate change will effect rainfall patterns. Very local effect			x	All insurable property lines of business can be effected by river flooding although damage tends to be restricted to ground floors and basements	x	x		Sewers for Adoption; CIRIA (Framework for assessing uncertainty in fluvial flood risk mapping (721); Culvert design and operation guide (C689)); Models require validation for use in Solvency II and Lloyds synidcates must report exposure in relation to Realistic Disaster Scenarios; API STD 610;	AIR 400 series occupancy coding using component based damage functions	Increasing resolution of digital terrain models and use of lower resolution, higher extent global models; Use of paleodata		Placement, construction and impacts of flood defenses could be better understood
C-Hydrological, Hydrogeological	*Flood due to dam failure*	x	x			x		Hydraulic modelling of the flood consequence of a dam breaking	Well assessed modeling. However, the estimation of the probability of dam breaking is a uncertain exercise	Possible increase in failure occurences due to increasing in extreme rainfall [29]	Uncertainty from dependence on projected increases in frequency and magnitude of extreme precipitation events [29]						x		Sewers for Adoption; CIRIA (Framework for assessing uncertainty in fluvial flood risk mapping (721); Culvert design and operation guide (C689)); BSI BS EN 12285				
C-Hydrological, Hydrogeological	*Drought*	x	x		x	x		Stationary EVA	Huge uncertainties due to the small amount of data at the local scale, not adapted for short series, does not use physical knowledge	Area affected by drought increases (water availability decreases) (Tab IV-1 IAEA); Projected increased frequency of extremely dry summers [14]	Likely (Tab IV-1 IAEA); 2/5 stars confidence due to low resolution of projection models [14]; local and regional effects									EDF NG Safety Cases and PSR			
C-Hydrological, Hydrogeological	*Extreme Groundwater level*		x			x		hydrogeological modelling		Potentially yes, due to the potential increase in extreme rainfall. However the link between extreme rainfall and extreme ground water level may be impacted by other factors.	Dependent on climate change effects on amount/timing of precipitation and humidity/temperature - hard to account for topography/vegetation/soil properties in model [28]						x		Sewers for adoption; CIRIA; API STD 610; BSI BS EN 12285	EDF NG Safety Cases and PSR			
D-Volcanic, Seismic, Geological	*Offshore and onshore landslide*		x			x		coupling landslide and hydrodynamic models at this continental scales semms to be very complex and time consuming for the moment	Unpredictable								x	Potential impact of landslide on offshore wind fams pile stability	BS PD 8010				
D-Volcanic, Seismic, Geological	*Sediment trasport and Sandbank*		x			x		Regional Ocean Model System General Length Scale Approach (Tidal Asymmetry and Residual Circulation Over Linear Sandbanks and their Implication on Sediment Transport: A Process-Oriented Numerical Study)	Used separately ROMS and GLSA provide horizontal and vertical movements, respectively.	Potential impact; Projected increase in sediment yield due to rainfall amplification through catchment runoff [31]	Models are still uncertain and don't account for temporal / spatial / altitudinal variation [31]	potential clogging of water intake by sand											
D-Volcanic, Seismic, Geological	*Geological instability, sinkholes, liquefaction, land slippage, etc*		x			x	x	Spatial Distribution Analysis (F/ Gutierrez, A.H. Cooper, K.S. Johnson, 'Identification, prediction and mitigation of sinkhole hazards in evaporite karst areas', 2008)	Limited amounts of data (spatial and temporal distribution of sinkholes, and conditioning factors). Assumes future subsidence phenomena will have the same probability and rate as past activity. Areas of low activity/no monitoring will not have the capability to predict occurences	Potentially yes, due to changes in extreme rainfall, there could be changes in the occurrence of landslides. Landslides are infact trigerred by extreme or long duration rainfall, [35].			x	x			x	x	API STD 594; API STD 600			Lack of liquifaction potential geological maps	Understand locations with liquifaction potential
D-Volcanic, Seismic, Geological	*Sandstorm (including dust storm and volcanic action)*		x			x		Atmospheric modelling of volcanic ash dispersion	Large uncertainties on the estimation of the return period of the extraction		Very dependent on climate change effects on precipitation, wind, and temperature, varies by location [27]	blockage of air filetrs by volcanic ash, 10-4											
D-Volcanic, Seismic, Geological	*Earthquake*		x			x	x	Probabilistic Seismic Hazard Assessment carried out in 4 steps: (1) Earthquake catalogue / tectonic review (2) Seismic source model development (3) Ground motion prediction equations (4) Hazard calculations. (5) In UK there are established PSHA techniques used to derive hazard. (6) Probabilistic Monte-Carlo simulation approach deriving a stochiastic catalogue of parameters from scientifically adjusted historical distributions [20]	As with all hazards, there are large uncertainties, but this is regarded as best practice. A large reliance is put on suitably qualified and experienced engineers making judgements on equation calibration and source data, which could be regarded as too subjective. Uncertainties are covered by expert illicitation and inherent conservatism in methodology. Existing techniques fairly well established, credible and backed up by significant research in			structural integrity	x	x	All insurable property lines of business can be effected by earthquake	x	x	x	SSHAC US guidance, Eurocodes, UBC 97, ASCE 4-98, IBC 2000, Models require validation for use in Solvency II and Lloyds synidcates must report exposure in relation to Realistic Disaster Scenarios, API STD 594, API STD 600	AIR 400 series occupancy coding using component based damage functions	Improvements to the deterministic methods are being investigated by European partners, but would not be readily transferrable to UK context Use of kinematic modelling to help constrain tail of the gutenberg-richter relationships. Use of next generation attenuation relationships	Lack of UK ground motion prediction equations - but due to low seismicity unlikely to be resolved. Effect of groundwater changes on existing fault reactivation? Lack of historic data for large earthquakes in the UK and UK specific ground motion prediction equations. Lack of understanding how earthquakes effect tall structures in the UK	Better understanding of potential range of ground motions for UK sites would be desirable
E-Biological	*Marine biological hazard*	x	x			x		(1) EDF NG Prediction and control techniques; (2) Stationary EVA	(1) Complex physics including biological behavior, hydrodynamics, temperature and meteorology, very site dependent; (2) Huge uncertainties due to the small amount of data at the local scale, not adapted for short series, does not use physical knowledge	Potentially yes, changing and increasing of marine species du to the sea water temperature increase [12]	Uncertain - ongoing data collation and assessment	water intake acces to cooling water					x	loadon offshore wind farms structures	Very little specific guidance - overarching safety principles on maintaining cooling water availability; API STD 594; API STD 600; API STD 602; BS PD 8010	Studies across EDF NG fleet & global nuclear	Development of biological models, hydrodynamics models, stochastic models	Lack of systematic understanding; Jellyfish blooming phenomena not really clear; Effect of climate change on marine biofouling; Alternatives to chlorination as suitable biofouling control ?	Emerging risk, very little knowledge
E-Biological	*Animals (including, for example rodent infestation)*					x								x					BS 61936; BS 7671				
F-Electromagnetic Hazard	*Space weather (including solar flares, Natural EMP)*	x	x		x			Peak over threshold EVA using (CLIMAX GLM?) provide fluence rates for return periods up to 10,000yr r.p.	Huge uncertainties due to the small amount of data at the local scale, not adapted for short series, does not use physical knowledge, up to 10-3			electronic control		Transmission system, electric control systems)						Extreme space weather impact on engineered systems and infrastructure, Royal Academy of engineer (2013)		A gap exists to confirm the extreme fluence rates and provide a methodology to assess the sensitivity of the electronics and/or EMI protection systems against the fluence rate]	emerging risk, very little knowledge
F-Electromagnetic Hazard	*Solar UV*					x		Laboratory testing of panels	Simulations run in labs are dependent on using a variety of lamps to provide similar UV exposure from the sun. Potential impacts listed to the right may not be directly from UV exposure but it is difficult to separate these.	Potentially yes, changes in the UV will depend on several factors including relative humidity (the change of which is extremely uncertain and expected to not change much, except over continental land areas where water is limited)	Very Uncertain							Solar - browning, adhesion, and debonding of solar panels					
G-Combinations	*Hazard Combinations*	x			x	x		(1) AIR's Touchstone modelling platform – risk can be quantified for a location or multiple locations across multiple perils; (2) Geospatial studies – can use shapefiles to represent regions of unmodelled risks e.g. sinkholes, where accumulating locations within these shapefiles aids in the quantification/identification of potential risk	To be investigated	Potentially yes, depending on the single hazards involved	Uncertain	depending on the combination						for offshore wind: combination of wave, tides and wind, (50 years return period + margins	OW sea combination in [1], ONR requirements in the UK, [3], WENRA requirement, [4, 5] and IAEA requirements, [6-8]		Numerical modelling		Lack of robust methodology; Covers all the range of natural hazard; Caused dramatic accidents (Fukushima)
H-Other	*Forest fire*						x	Probabilistic Monte-Carlo simulation approach deriving a stochastic catalogue of parameters from scientifically adjusted historical distributions	Model meets the wide spectrum of forest fire risk management needs	Yes - warmer and drier weather will make forest fires more frequent, [30]	Uncertainty from dependence on projected temperature increases, variation in other contributing factors (ex. Relative humidity), and spatial variation [30]	x			All insurable property lines of business can be effected by forest fire	x			NFPA for Fire Risk Assessment, Models require validation for use in Solvency II, API RD520, API STD 594, API STD 600, API STD 607, IEC 60331, IEC 60332, IEC 60079, Multiple NFPA standards				
H-Other	*Meteorite impact*	x	x	x				(1) Estimates of frequency of meteorite impact causing Tsunami to HPC is calculated linearly (area x no of occurrences..); Estimated average return period for given meteorite diameter (2) Spatial Decision Support System architecture (not very mature though) [24]	(2) SDSS is still new and need improvements, designed for potential impacts in urbanized areas, working on including submersion waves from hitting the ocean (tsunami) [24]			sea waves caused by meteorite impact causing flooding of the platform, 10-7											

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IPCC terminology on likelihood of occurrence / outcome: (Tab IV-1 IAEA)	Probability
Virtually certain	>99%
Extremely likely	> 95%
Very likely	> 90%
Likely	> 66%
More likely than not	> 50%
About as likely as not	33-66%
Less likely than not	< 50%
Unlikely	< 33%
Very unlikely	< 10%
Extremely unlikely	< 5%
Exceptionally unlikely	< 1%