CDOIF v.Jan 2024

Adapting to Climate Change

Understanding the risks of a changing climate, and managing them safely

Developed in collaboration through CDOIF Natech and Climate Change Adaptation working group

Contents

Note:
These slides contain 3 sections and not all slides suit all audiences

Section 1 provides an introductory overview, suitable for all levels of management

Section 2 provides detail on how adaptation can be embedded into management systems, for management system leads

Section 3 provides a general reference resource of case studies and further information which can be referred to where relevant to a specific installation

Section 1

Natech risk management and climate change adaptation

Developed in collaboration through CDOIF Natech and Climate Change Adaptation working group

What is a Natech?

Natural Hazard Triggered Technological Accident (Natech)

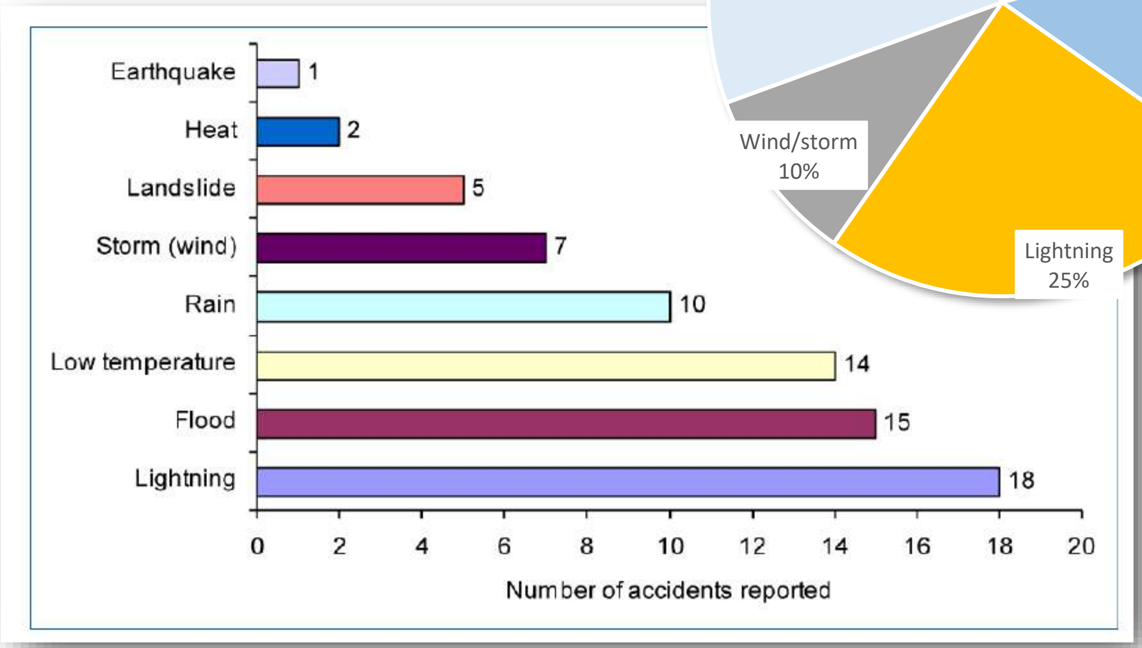
- Industrial accidents with natural causes, such as flooding, storms, lightning, high/low temperatures, sea level rise, subsidence, wildfire etc.
- Natechs can degrade protection measures, causing harm to people and the environment … and assets/businesses/supply chains
- Planning for Natechs is essential for process safety

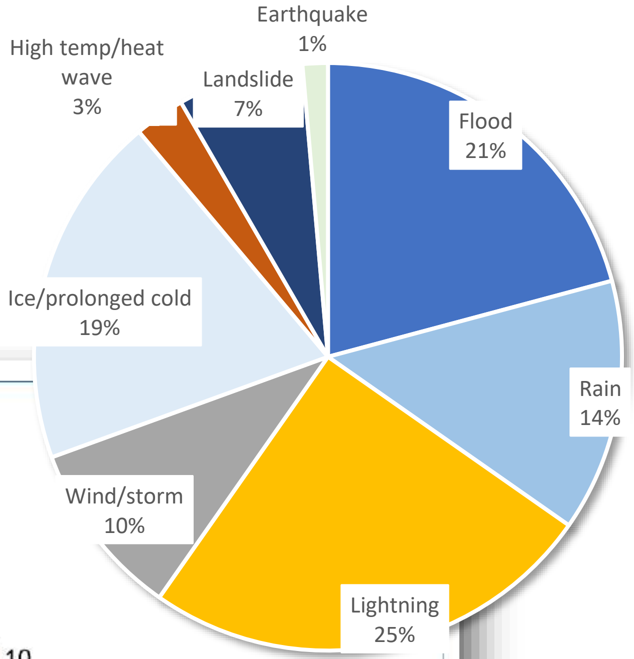
Common Natech characteristics

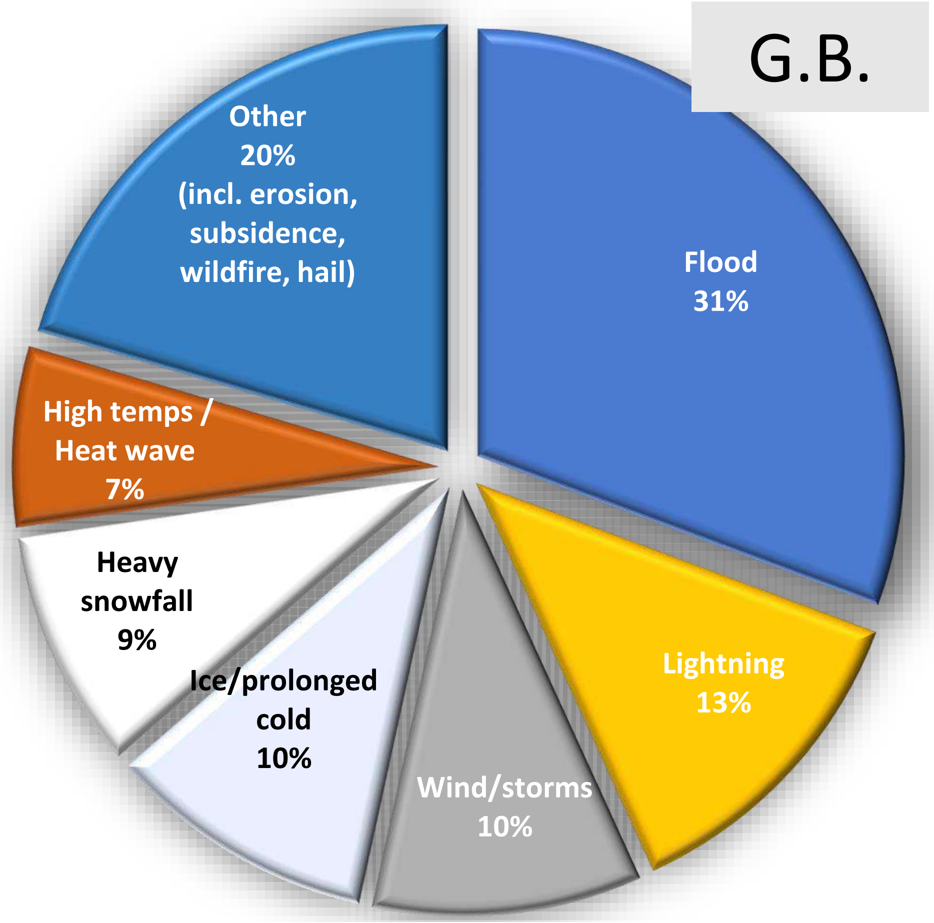
- Wide area impact – both local impacts and wider area disruption (such as power and communications outages, supply chain disruption, cascading risks)
- Existing control measures (barriers and systems) not designed for present day and future environmental extremes – the climate has already changed
- Common cause failures across barriers
- Multiple, simultaneous failures & releases
- Impact on preventive and mitigatory measures – including emergency responders
- Potential for multiple simultaneous major accidents (e.g. East Coast surge)

What are the most common extreme weather/ Natech threats at present?

Natech accidents reported by 5 EU countries (1990-2009) MAHB, Lessons Learned Bulletin No.6 – NaTech accidents, 2014







Extreme weather threats to GB establishments (Survey by CDOIF, 2021)

What does a Natech look like?

- It could be horrific....

- Dronka, Egypt, 1994
  - Military fuel depot storing gasoline and jet fuel
  - Severe storm resulted in infrastructure damage at and around the installation
  - Burning fuel, ignited by lightning, spread through a village on flood waters
  - >400 people killed

  - There was no secondary containment in place to contain the release – if well designed bunding and good drainage systems had been in place, the burning fuel may have been contained on the site without spreading the fire
  - Land use planning aspects – the fuel depot was located close to a village… too close?
  - Was this Natech risk even recognised?

Northampton, 1998
A UK wakeup call?

Aidan Whitfield (2003) Assessing and reducing flood risks on Major Hazard sites – IChemE Hazards Archive (XVII)

Climate impacts can increase risk of permit non-compliance and impact operations…

High ambient temperatures can impact industrial plant and cooling systems either directly due to the temperature increase or lack of cooling water, or other impacts such as increased risk of biofouling

This can:

- threaten the ability to maintain operations within permit limits (e.g. cooling water temperature discharge limit)
- reduce the generating efficiency or throughput of the plant itself
- necessitate shutdown for safety

Such an event occurred in Europe in 2018/19, resulting in nuclear plant power output reduction or outage

See Natech case studies which include further heatwave impact examples

How does climate change impact safety and environmental protection?

Frequency and severity of events

- Climate change has increased the frequency and severity of extreme weather events and is causing other impacts such as sea level rise and increased receptor vulnerability

Control measure failure or degradation

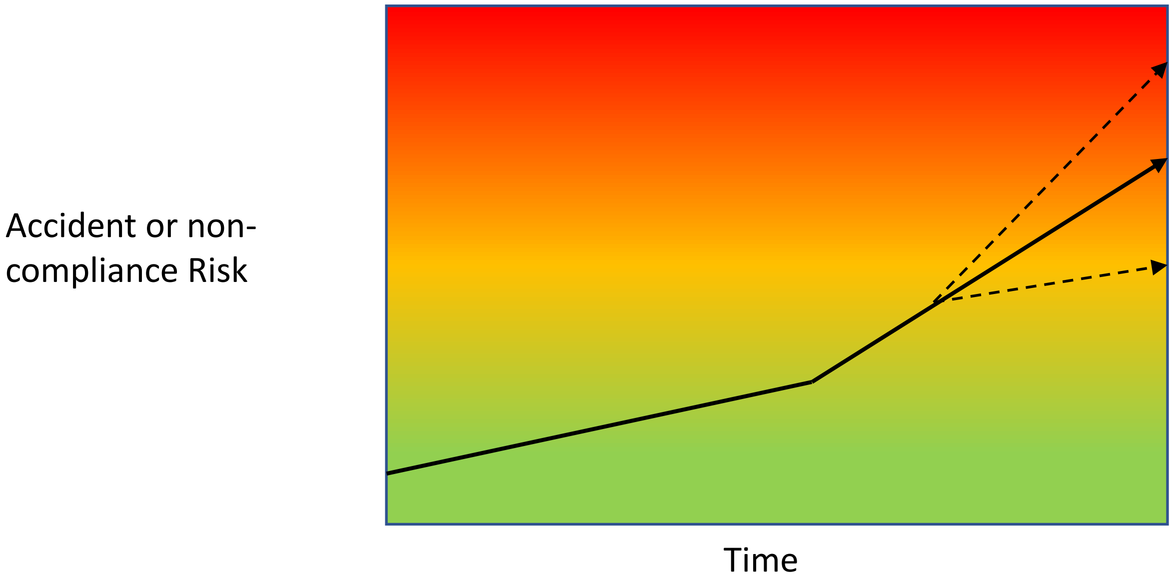
- Due to increasing risk of natural causes, there is an increased risk of control measures failing or degrading, increased risk of supply chain/utility disruption and thus an overall increasing risk of accidents or other non-compliance events [if risks are unmanaged]

Receptor vulnerability

- Climate change impacts are making receptors more vulnerable to harm from accidents, which can increase the severity of impact from pollution

The influence of climate change on the risk of industrial accidents or other non-compliance

“Natech risk is expected to increase in the future” JRC (2022)



Climate change will result in increased risk of accidents, if implications for safety and environmental protection are not managed – we need to adapt to control risks

What is the priority for action?

The present

“Climate change is happening now. It is one of the biggest challenges of our generation and has already begun to cause irreversible damage to our planet and way of life.”

UK Climate Change Risk Assessment 2022

The future

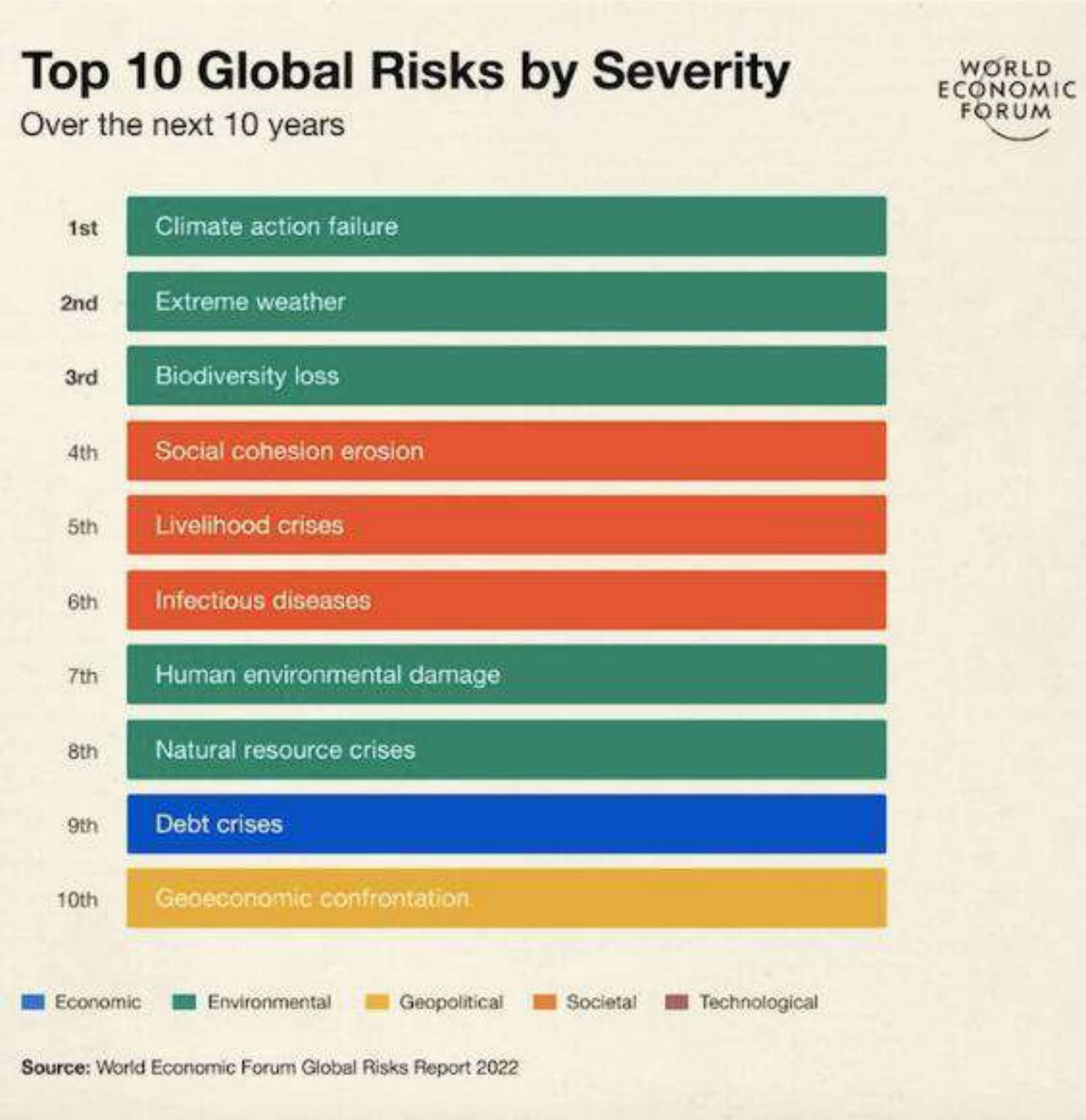
“Many of the risks facing the UK are likely to increase both in magnitude and frequency as a result of climate change, and risk assessment cannot be conducted without acknowledging this fact.

Climate change is an ever more significant risk facing the UK and action to address it needs to be undertaken rapidly and as a priority.”

“Preparing for Extreme Risks: Building a Resilient Society”
House of Lords 2021

What's the priority for action?

- The World Economic Forum rated climate mitigation and adaptation as the top global risk in 2022
- With extreme weather the second highest risk



What is the difference between adaptation and mitigation?

Climate change mitigation

- A human intervention to reduce the sources or enhance the sinks of greenhouse gases (GHGs).
- Driving the net zero agenda, the need for decarbonisation of energy systems, greater efficiencies and circular economies.

Climate change adaptation

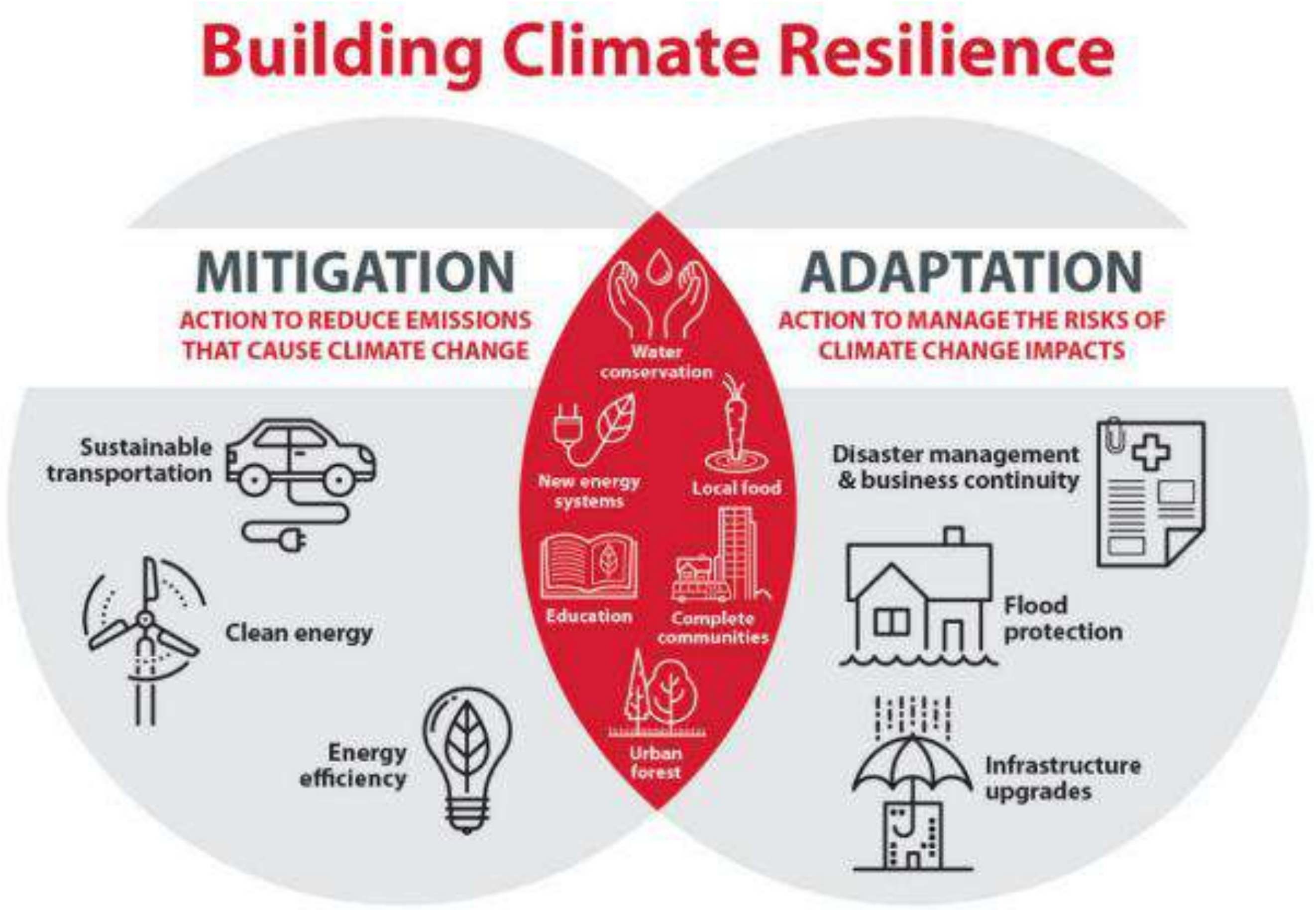
- The process of adjustment to actual or expected climate and its effects.
- In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities.
- In some natural systems, human intervention can facilitate adjustment to expected climate and its effects.

Resilient net zero = mitigation + adaptation

- Climate mitigation, resource efficiency and adaptation sometimes seen as separate issues

- Encourage ‘integration’ or ‘systems thinking’

- Consider climate impacts in short, medium and long term on compliance, including during transition to net zero



How can risks be managed safely?

Ensuring Natech and climate change risk management and decision making is embedded across the whole business management system – bringing resilience benefits, beyond environmental protection and safety, and avoiding wider costs of climate impacts.

Applying process safety leadership and environmental management principles, especially management of change, to events/scenarios with natural causes.

By understanding how risks may change in the future and taking the necessary measures, at an appropriate time, to ensure risks remain ALARP and permit compliance is maintained.

How can uncertainty be managed?

Adaptive management - description

- The process of iteratively planning, implementing and modifying strategies for managing resources in the face of uncertainty and change
  - i.e. Plan-Do-Check-Act cycle to deliver continuous improvement

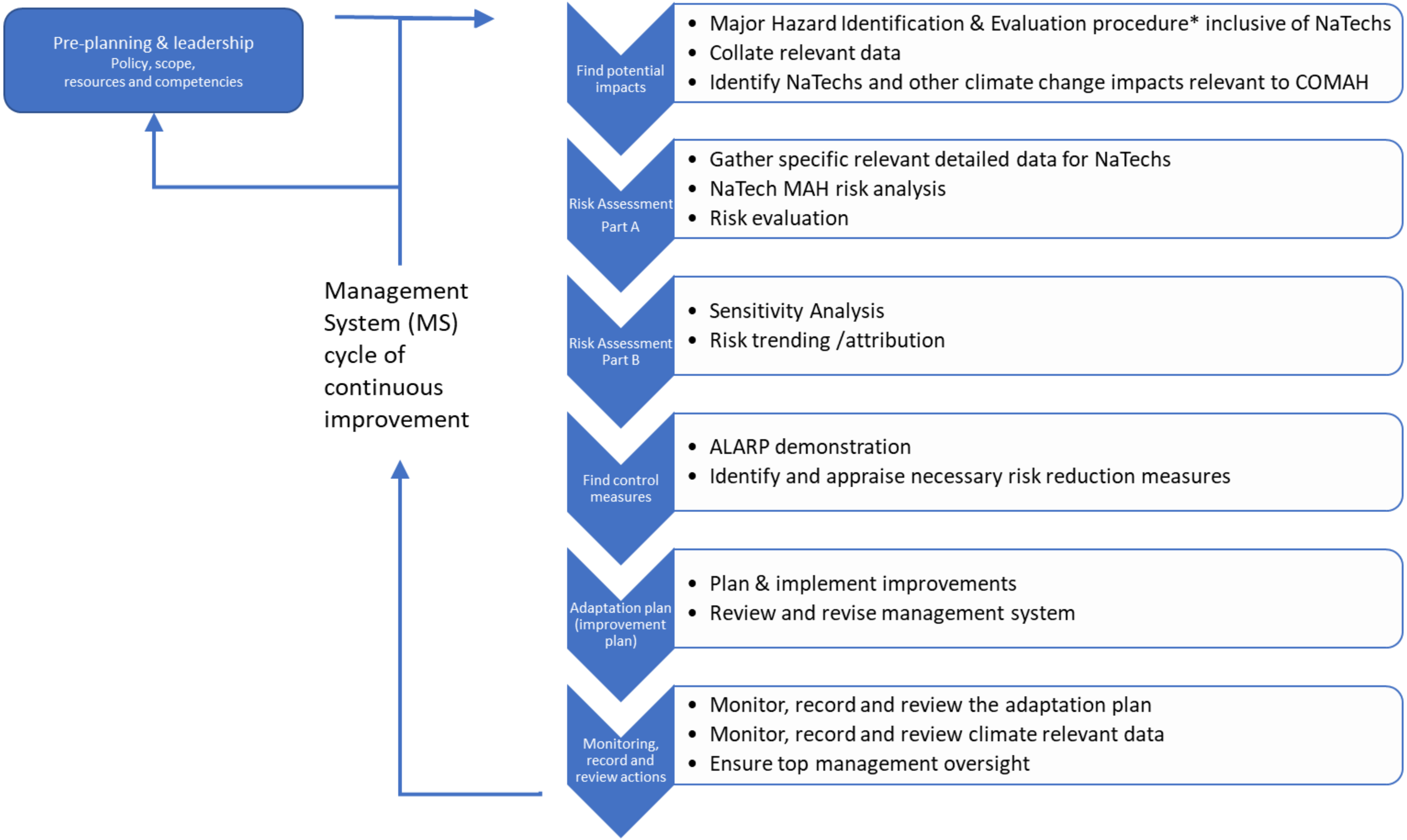
Adaptive management - implementation

- Implement adaptive management approaches within management systems – considering various possible climate scenarios, then iteration and continual improvement
  - Commitment to adapt
  - Keep risk assessments up to date with the best current knowledge of present + future projected climate conditions
  - Consider risk reduction measures and develop an improvement plan
  - Monitor Natech relevant information & performance indicators
  - Periodic review and revision of risk assessments, improvement plans and adequacy of the management system

Management systems

- Climate adaptation is a ‘thread’ which runs throughout management systems

How can uncertainty be managed?



How can uncertainty be managed?

- Implement best practice, including:
  - ISO 14090 (adaptation to climate change)
  - ISO 14091 (assessing climate risks)
  - BS 8631 (adaptation pathways)

- Gather current data and understanding of future weather projections (e.g. Met Office UKCP18) and other climate change impacts to inform risk management

Getting started….
…..ask yourself:

- Does your organisation have the leadership, systems, resources and competencies required to manage climate relevant risks and opportunities?
  - ➢ See ISO 14090, Clause 5
- Have you assessed the safety and environmental risks to your business, exploring how it might be vulnerable to the range of climate impacts predicted by Met Office to occur under a 4°C global warming scenario? This is sometimes called 'stress testing' the organisation to possible climate impacts
  - ➢ See ISO 14090, Clause 6 and ISO 14091
- Have you exercised your emergency plans to see how they would cope with various extreme weather accident scenarios?
  - ➢ This could be a joint multi-agency test to explore off-site vulnerabilities

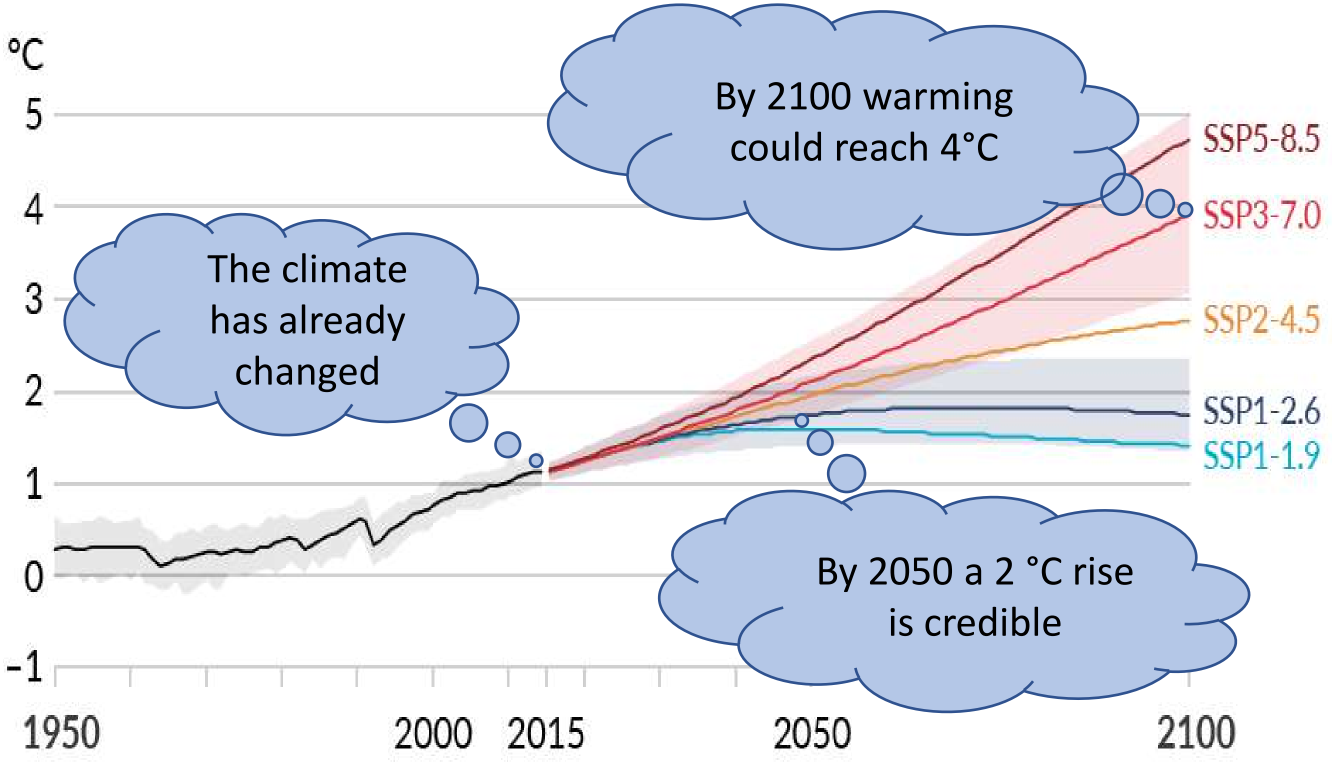
"Our thinking needs to change faster than the climate"

Climate science – future projections based on differing emissions scenarios/pathways

Predicted global warming ….
…for different Representative Concentration Pathways (RCPs)….

RCP	Change in temperature (°C) by 2081-2100
RCP2.6	1.6 (0.9-2.3)
RCP4.5	2.4 (1.7-3.2)
RCP6.0	2.8 (2.0-3.7)
RCP8.5	4.3 (3.2-5.4)

…..and Shared Socioeconomic Pathways (SSPs)



Change in global temp c.f. pre-industrial baseline

What do regulators expect to see?

Manage risks of a changing climate

- Regulators expect operators to manage risks of a changing climate, to maintain compliance with relevant environmental and safety legislation

  e.g. The operator of a COMAH establishment would be expected to:

  - assess how major accident risks associated with extreme weather events and other climate change impacts will vary over the lifetime of their establishment

  - plan how to respond to these changes, and implement modifications at an appropriate time, to manage both present and longer-term risk to ALARP levels
- And at nuclear sites we have developed a Position Statement on the regulator's expectations for [Use of UK Climate Projections 2018 (UKCP18) by the GB Nuclear Industry]

Integration of adaptive management techniques

- Regulators expect integration of adaptive management techniques within environmental and safety management systems – i.e. embedding adaptation

What will regulators expect to see?

Met Office (2022)

Use UK climate projections UKCP18* to inform local impacts to regulated sites

Derived projections - include projections at a global mean warming of 2°C and 4°C

*or equivalent data when superseded

Operators will

- **Understand and manage present day risks** (potential extremes, including historic data baseline, e.g. Met Office extremes and state of the climate reports and any available allowances, e.g. flood)
- **Assess the risks associated with a 4°C rise by 2100** (identify/screen potential impacts to the facility – stress testing)
- **Plan to manage the risks associated with a 2°C rise by 2050**, without creating obstacles for future adaptation - avoiding lock-in
    - **at an appropriate time, adopt measures to maintain compliance and maintain risks As Low As Reasonably Practicable**
- **Monitor, review and revise in subsequent years** (establish indicators, validate assumptions, review and revise assessments and plans as new data becomes available)

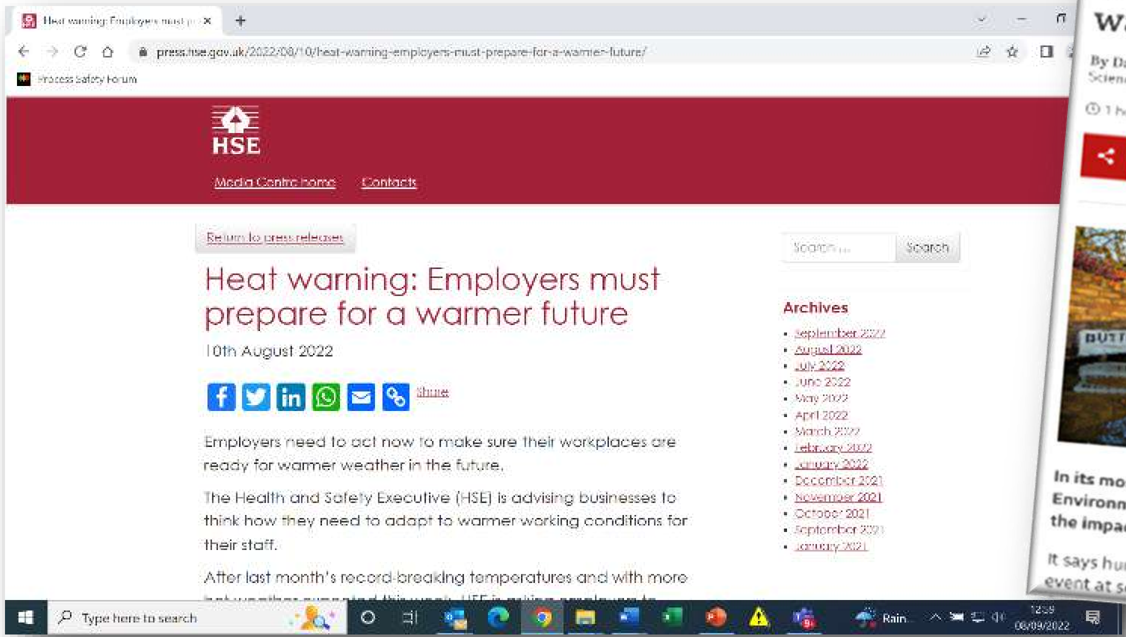
More detailed and/or longer timescale assessment and planning may be required for higher risk/higher vulnerability installations (e.g. expanding assessments to include a wider set of RCP data, incl. H++ scenario).

Less detail may be acceptable for short life installations or where there is low risk/climate impacts are not significant for compliance and safety.

Where can I get more information?

Recent media campaigns

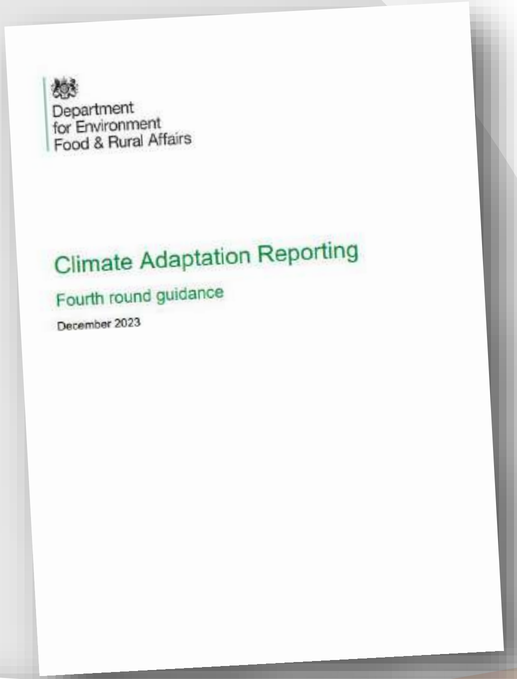
[HSE (2022)]

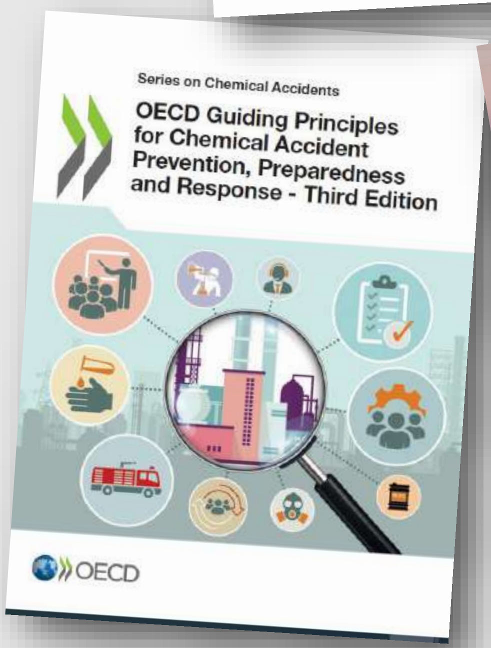


Where can I get more information?

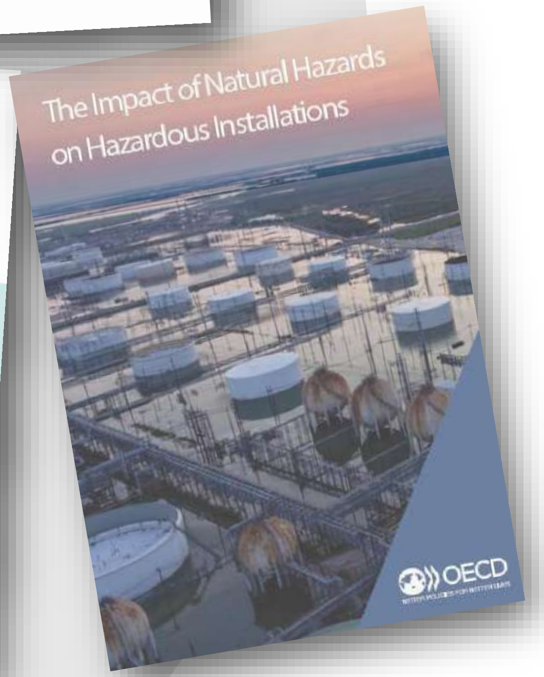
- Get started by considering and, where appropriate, implementing EPR guidance
  - Develop a management system: environmental permits - GOV.UK (www.gov.uk)
  - Climate change: risk assessment and adaptation planning in your management system - GOV.UK (www.gov.uk)

    (See section "A changing climate")
  - Adapting to climate change: industry sector examples for your risk assessment - GOV.UK (www.gov.uk)
- Consider other relevant UK and international guidance, for example from DEFRA or from OECD





OECD (2023)



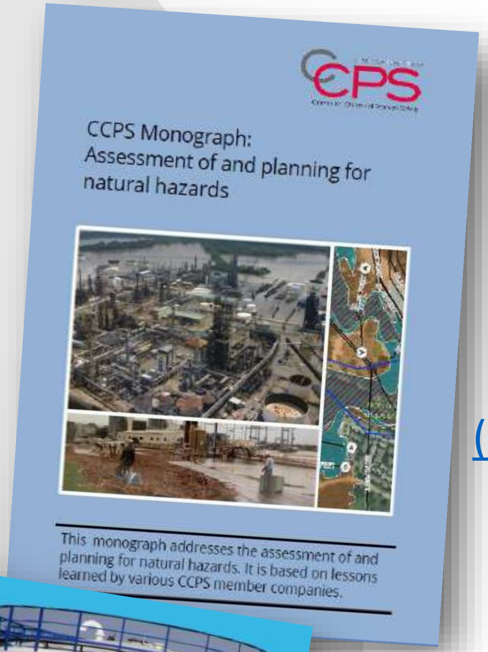
OECD (2022)

Where can I get more information?

- Benchmark your risk assessment and control measures against guidance from CCPS, CIA, MAHB

- Talk to your regulator and collaborate locally – there are many resources and networks available, eg,
    - Adaptation Scotland
    - London Climate Partnership
    - Yorkshire and Humber Climate Commission
    - Sustainability West Midlands

CIA (2021)



CCPS (2020)

MAHB (2020)

Where can I get more information?

- IEMA CC Adaptation Practitioner guide and IMechE heat impacts and rising seas reports
- Various EC Natech publications at MINERVA . e.g. JRC reports
    - Natech risk management
    - Understanding Natech risk due to storms
- Sharing lessons across sectors….

  PSF Carmont train accident Learning Brief
- And a couple of great TED talks from Alice Bows-Larkin and Vicki Arroyo
- The knowledge base on Natechs and adaptation continues to evolve rapidly

IEMA (2022)

JRC (2018)

IMechE (2019)

JRC (2022)

IMechE (2023)

What work is ongoing?

- Met Office Hadley Centre collaboration
  - Continuing work on UKCPs. Renewed focus on outputs for industry.
- Environment Agency - in collaboration with partners & industry
  - Maintaining guidance, training strategy, materials and inspection guidance, including ongoing CA campaign and training (Started April 2023)
  - Continuing collaboration, for example through CDOIF and the Infrastructure Operators Adaptation Forum (IOAF)
- Continuing international Natech research to understand impacts, learn lessons and inform international policy (e.g. JRC)

EA2025
A NATION RESILIENT TO CLIMATE CHANGE

EA2025
HEALTHY AIR, LAND AND WATER

EA2025
GREEN GROWTH AND A SUSTAINABLE FUTURE

Environmental and safety regulation has a crucial role in ensuring infrastructure resilience and mitigating the potential increase in industrial risks – especially ensuring resilience of net zero infrastructure

There is a synergy between mitigation and adaptation - there is a synergy between environmental protection, safety and resilience

In summary

The need for climate change adaptation

- The climate has changed and continues to change.
- Without adequate management, risks will increase, including process safety risks. There have already been many high profile industrial major accidents with natural causes we need to learn from.
- Safety and environment regulators expect climate change adaptation to be embedded into management systems, to maintain control of major accident hazards.
- This requires operators of high hazard sites to ensure:
  - Leadership, resource and competencies
  - Climate change risk assessment - assess for 4°C, plan for 2°C, and avoid lock-ins
  - Plan, monitor, record and review, with top management oversight……….

  …………delivering Continual Improvement
- International standards, guidance and case studies are available to support this work.

Section 2

A closer look at the major hazard management system cycle

What is the major hazard management system cycle?

A process safety approach to adaptation

- Applies the principle of continuous improvement to ensure there is adequate planning, monitoring, recording and reviewing, with top management oversight.
- Climate change adaptation is embedded into management systems, to maintain control of major accident hazards.
- Potential MAH due to a changing climate are identified, the risks from each are identified, control measures are designed and implemented at an appropriate time …

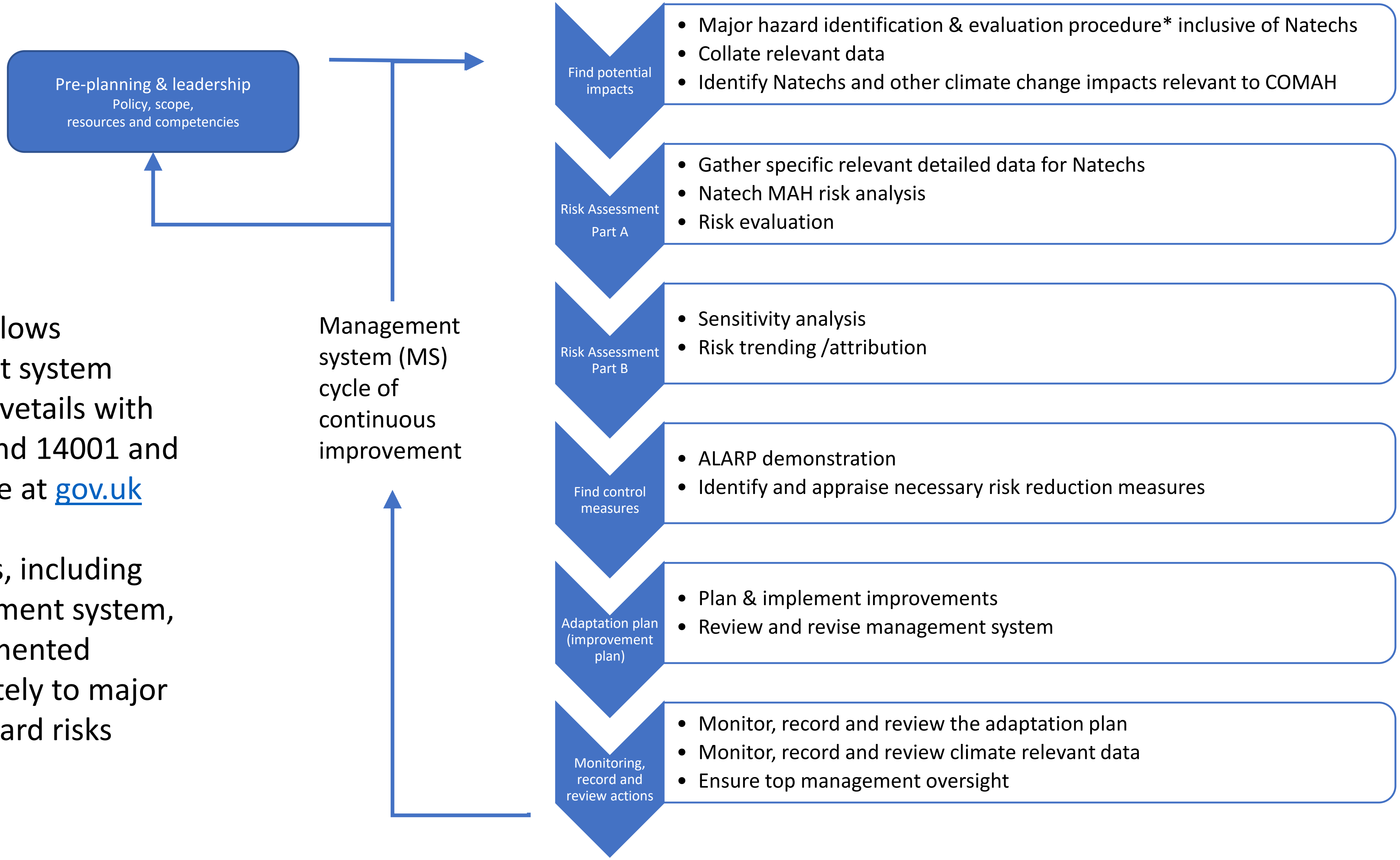
… and the actions taken are reviewed to assess whether further measures are necessary

The COMAH principle of continuous improvement

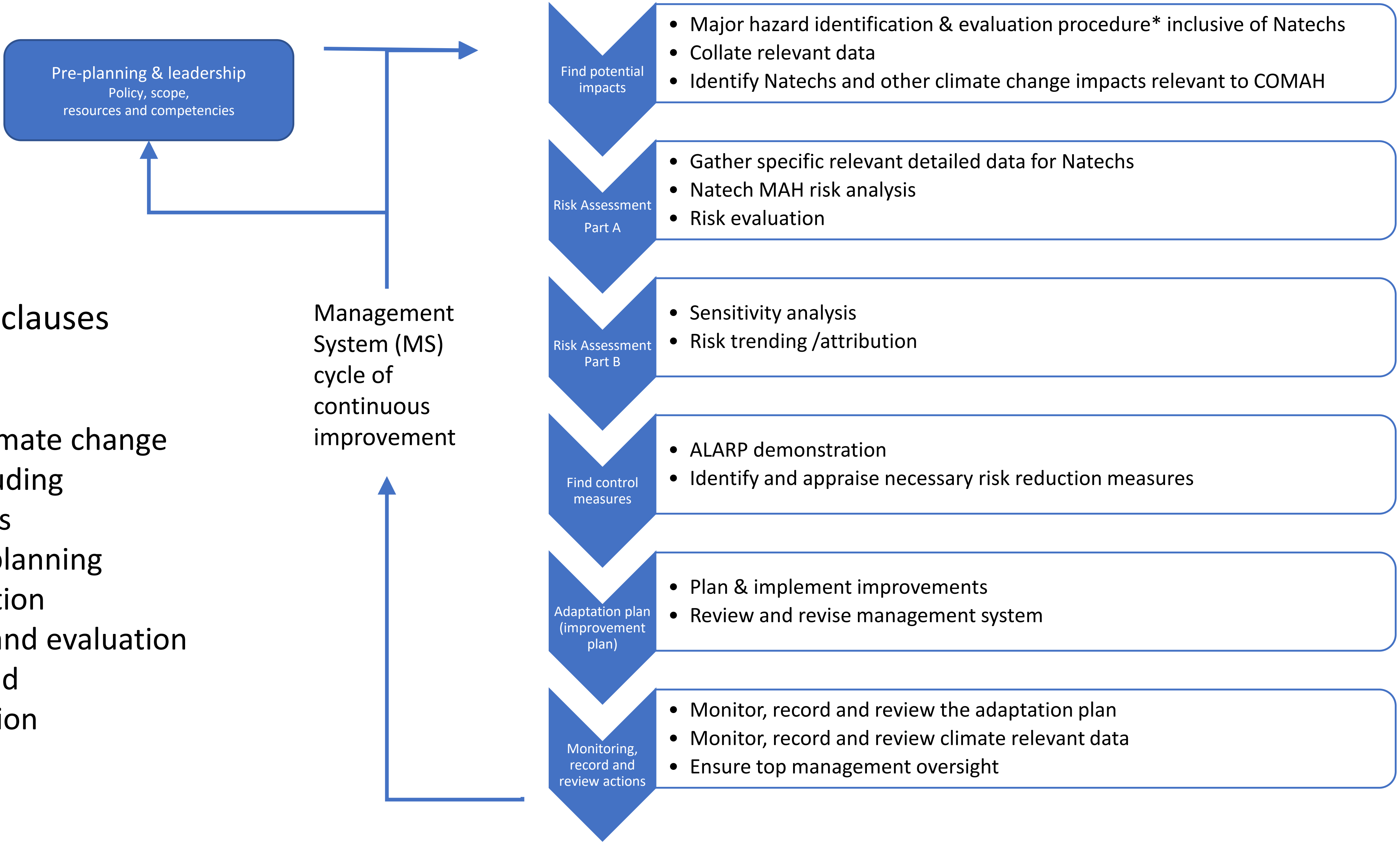
Plan-Do-Check-Act

Adaptation & the major hazard management system cycle

- Structure follows management system cycle and dovetails with ISO 14090 and 14001 and EPR guidance at [gov.uk](gov.uk)
- All measures, including the management system, to be implemented proportionately to major accident hazard risks



Adaptation & the major hazard management system cycle



Key ISO 14090 clauses

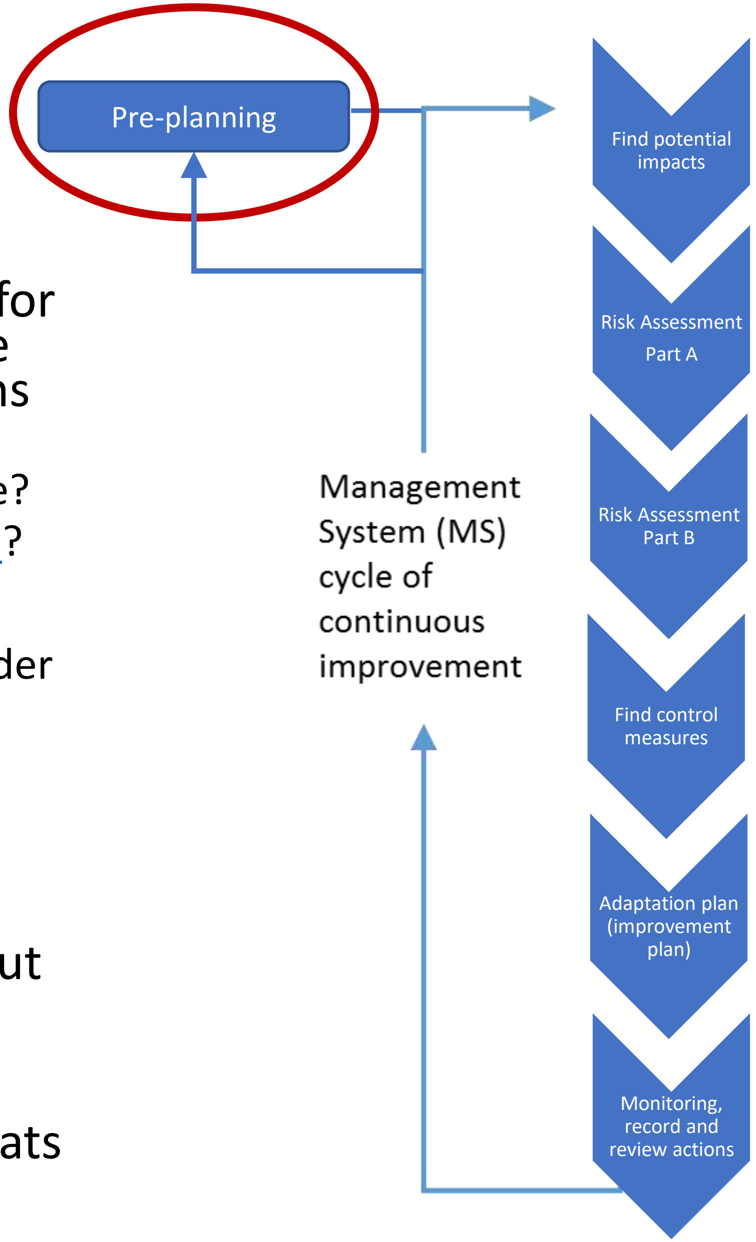
5. Pre-planning
6. Assessing climate change impacts including opportunities
7. Adaptation planning
8. Implementation
9. Monitoring and evaluation
10. Reporting and communication

Pre-planning & leadership

What is the organisation's adaptive capacity?

i.e. The operator's ability and resources to adjust to changes in the climate and weather

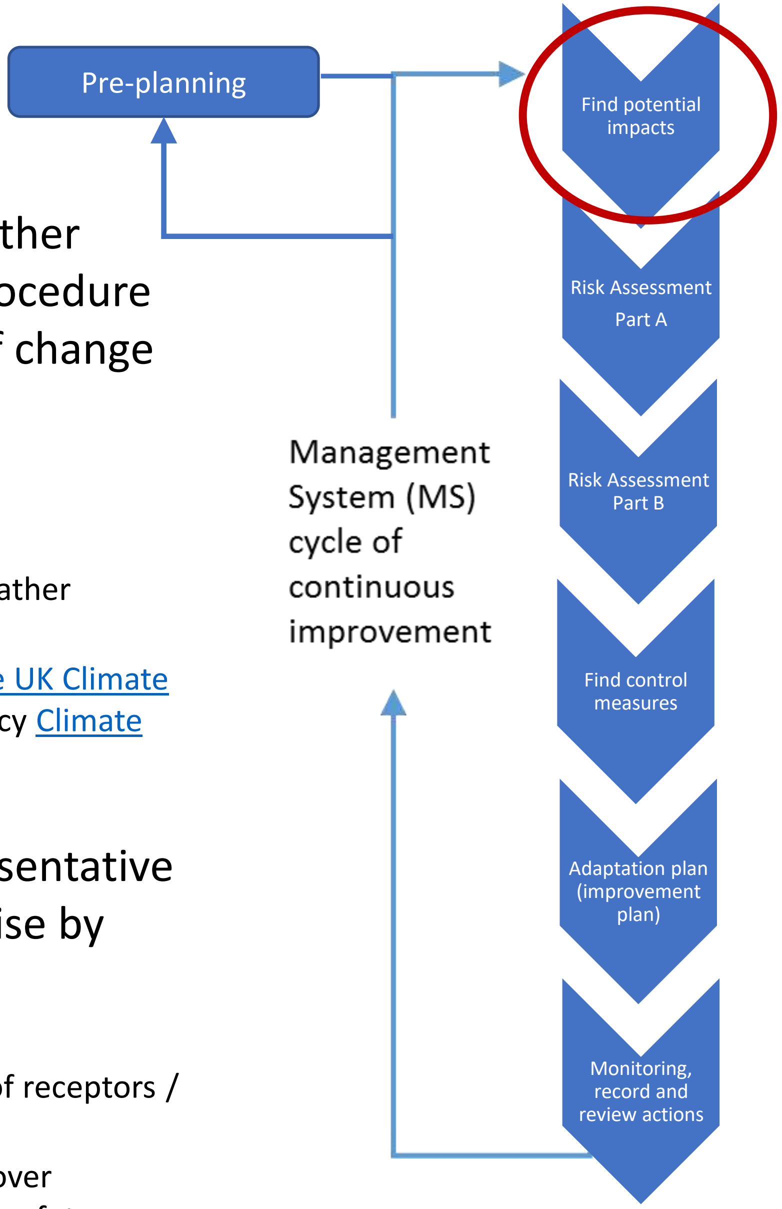
- **Policy –** demonstrating leadership of, commitment to, and accountability for implementing climate change adaptation management and to incorporate and embed climate change adaptation into its policies, strategies and plans for management of major accident hazards.
  - Is there a commitment to adapt? What is the operator's safety/adaptation culture?
  - What ambition? - Enough to comply, or striving for Best Practice? A just transition?
- **Scope –** clearly define scope of adaptation planning activities
  - Limited to managing environmental/safety threats and risks, or to also include wider opportunities (e.g. planning for Net Zero transition/opportunities)?
  - Just COMAH (major accidents), or also other purposes (EPR/PPC, CCA, planning, TCFD)?
  - As part of wider business resilience planning?
  - Consider adopting ISO 14090 within 14001 management system
- **Resources & competencies –** ensuring organisational capability to carry out necessary work. Defines climate change skills and competencies required throughout the organisation and required resources, including top management commitment and finance. Climate change adaptation embedded throughout all roles and responsibilities so that emergent threats can be identified.



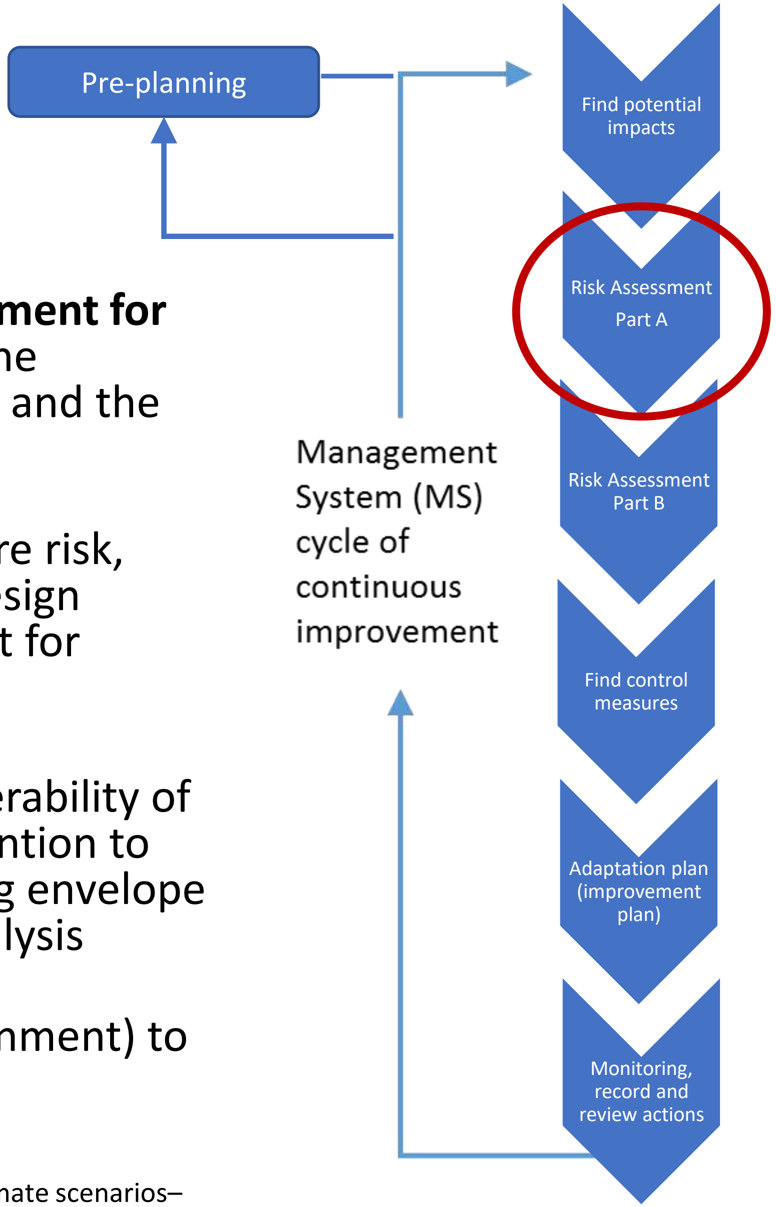
Find potential impacts

Screening / stress testing impacts associated with a 4°C rise by 2100

- **Major hazard identification & evaluation procedure -** Ensure Natechs, including weather threats and linked climate change impacts, are embedded in management system procedure for risk assessment (Hazard identification, analysis and evaluation) & management of change
  - Consider ISO 14091 (assessing climate risks)
  - Consider causation, degradation and escalation factors, plus data sources
  - Define criteria with regards review/revision of risk assessments (including for new facts/knowledge)
- **Collate relevant data -** Gather Natech relevant data, including:
  - Existing Natech relevant major accident risk assessments, incident case studies (local and global), and local weather records and sector risks guidance (e.g. EPR guidance or sector reports, such as from Energy UK)
  - Climate projections (UKCP18) of 4°C rise by 2100. Data sources include Met Office Derived Projections and the UK Climate Change Risk Assessment. Also, tools at UKCIP , UKCRP (e.g. Climate Risk Indicators) and the Environment Agency Climate Impacts Tool
  - Other adaptation relevant data (land use planning info and financial assessments etc)
- **Identify Natechs** (initiators and escalation mechanisms) - Identify and describe representative weather/climate change relevant Natech hazards & scenarios associated with a 4°C rise by 2100 scenario
  - How could extreme weather initiate or exacerbate major accidents (MAs)?
  - Could other climate change impacts initiate or exacerbate MAs? (e.g. rising sea level / increased vulnerability of receptors / geological impacts)
  - Consider how climate change projections might increase / alter threats and risk at the establishment location over proposed installation lifecycle. A major accident scenario that is not credible today might become credible in the future.



Risk assessment – Part A



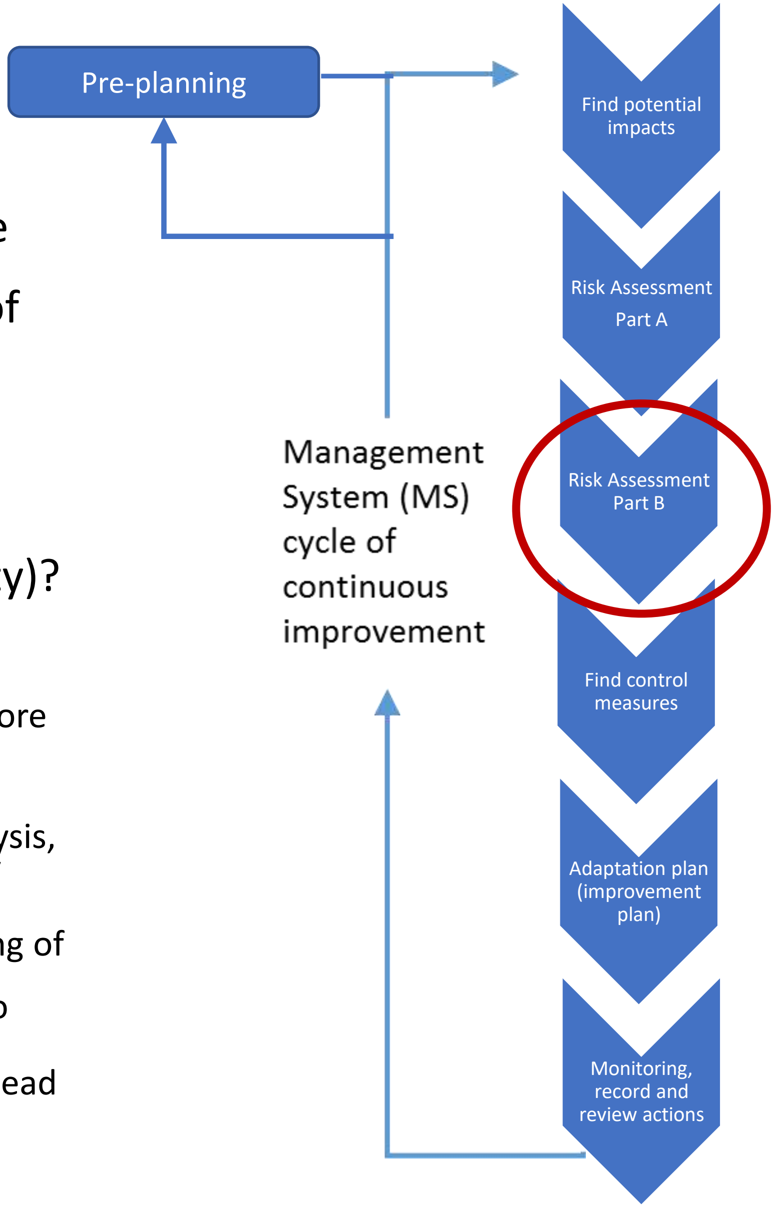
- **For impacts identified as relevant for a 4°C rise, carry out more specific risk assessment for various scenarios (including: i) present day, ii) 2°C by 2050 and iii) 4°C by 2100) -** The present-day scenario and info should be covered by current Natech risk assessment and the approach for this will inform how to undertake future scenario risk assessments.
- **Gather specific relevant detailed data for Natechs –** Past, present and future* meteorological, flood & coastal risk, river flow (high/low), sea level, temperature, fire risk, geological data etc. Also, topographical, general arrangement, equipment data / design parameters / vulnerabilities, and site maps / general arrangement drawings relevant for weather relevant threats and climate change impacts.

- Carry out **Natech MAH risk analysis** in accordance with MS procedure, linking vulnerability of equipment / procedures to extreme weather and other climate threats, paying attention to original design criteria, to determine if equipment remains within the safe operating envelope or if there is increasing risk of failure leading to increasing MAH risk (i.e. Natech analysis within process safety risk assessment).
- **Risk evaluation** - Compare present day and potential future risk (people and environment) to tolerability criteria.

* For prediction under future climate scenarios, UKCP18 is currently the basis of good practice modelling with data available for different climate scenarios– see Met Office projections/predictions

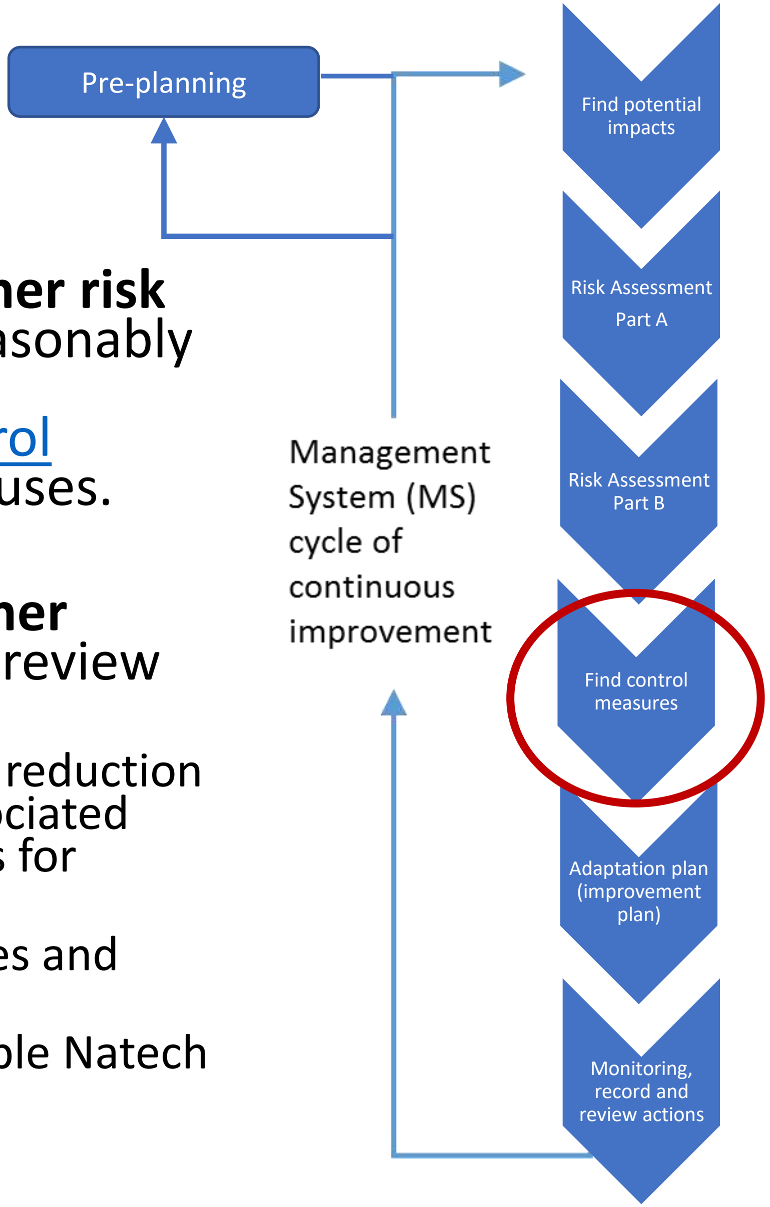
Risk assessment – Part B

- **Sensitivity analysis –** Proportionate sensitivity analysis of the conservatism of the assessment; especially important where climate change influenced risks are high and risks may not remain tolerable in the future. Using data from a wider range of climate projections (2°C and 4°C, H++, RCPs 2.6, 4.5, 6.0 and 8.5, SSPs) can help build understanding of how climate impacts may change with different future scenarios and in turn what that might mean for establishment vulnerability and major accident risk
- **Risk trending/attribution** - How does major accident risk correlate to the threat from predicted severe weather events/climate impacts (frequency and/or severity)?
  - Have risks increased significantly from when the establishment was designed/built to present day?
  - Are today's risks tolerable (ALARP)?
  - Are there dominant risks from specific weather events and/or plant areas where risk is changing more rapidly?
  - Will risks remain ALARP in the near future – to the point of next risk assessment review?
  - Will risks remain ALARP over the asset/installation/establishment lifetime? As with sensitivity analysis, exploring data for a range of climate projections can help build understanding of risk trends for any natural causes which pose or will pose a greater level of risk.
  - Considering equipment design specifications and envelope of safety - What is current understanding of the predicted rate of change of risk over time? Will risks remain tolerable in the future or will the equipment design envelope be exceeded, increasing risk of failures and thus increasing MAH risk to become intolerable?
  - Need to understand rate of change of risk in terms of any potential future risk reduction measure lead times.



Find control measures

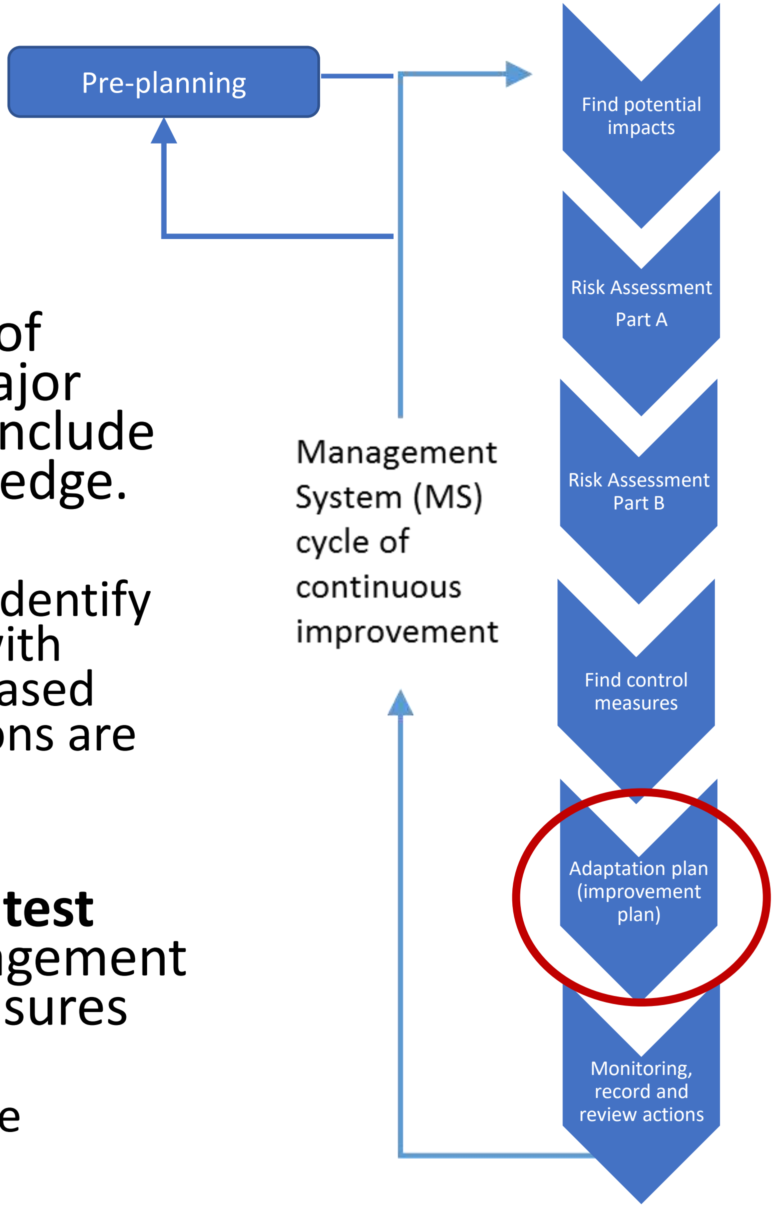
- **ALARP demonstration**
- If present day risk is not ALARP then **identify and appraise further risk reduction measures** to find those control measures that are reasonably practicable (including any necessary further data gathering and management systems revisions). Use safety and pollution control hierarchies to guide measures to control foreseeable natural causes.
- If future risks may not remain ALARP due to changing weather threats/climate impacts, **identify appropriate management/other measures to ensure risk will remain ALARP** both until the next review point and **over installation lifetime**. For example:
  - Ensure new designs incorporate flexibility/upgradability to allow risk reduction to be implemented in the future – e.g. when planning measures associated with 2°C by 2050, ensure actions or decisions do not create obstacles for future adaptation that may increase risk later (known as “lock-in”).
  - Review existing measures associated with people, plant and processes and identify potential measures to improve resilience
  - Ensure emergency plans will achieve their outcomes under foreseeable Natech conditions/events



Adaptation plan (Improvement plan)

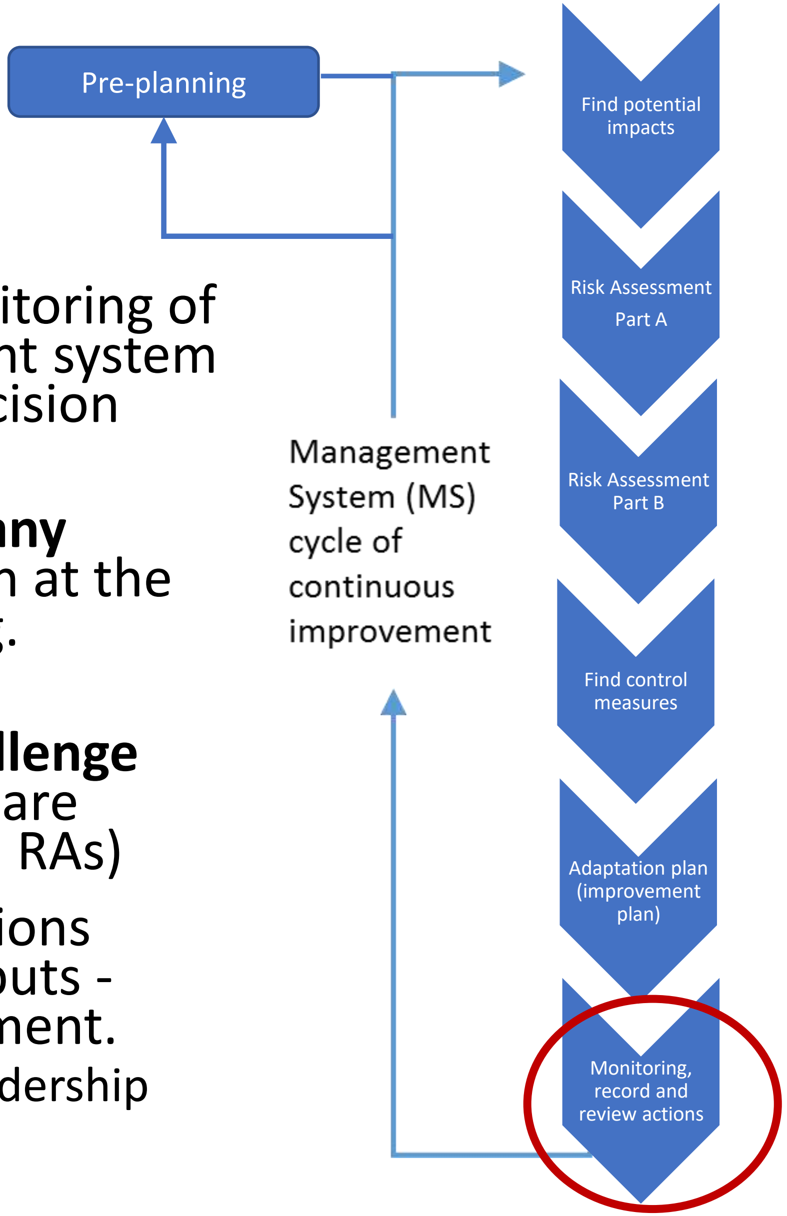
- **Plan & implement improvements** - adoption and implementation of necessary measures required, at an appropriate time, to ensure major accident hazard risk is ALARP and in future will remain so. This to include planning to gather further info/data where there are gaps in knowledge.
  - Consider an adaptation pathways approach (BS 8631)
  - Develop **performance indicators and climate impact indicators** and identify key points/thresholds when substantial decisions need to be made with consequences or lead-in times >5 years (e.g. infrastructure, nature-based solutions, supply chain contracts) so that timely management decisions are ensured

- **Plan to audit, review and revise management system and plan to test emergency control measures through exercises** - ensure the management system remains adequate for weather Natech and plan to test measures through Natech relevant emergency plan tests/exercises
  - Plan to make any necessary change to ensure Natechs and adaptation are embedded within all aspects of the management system

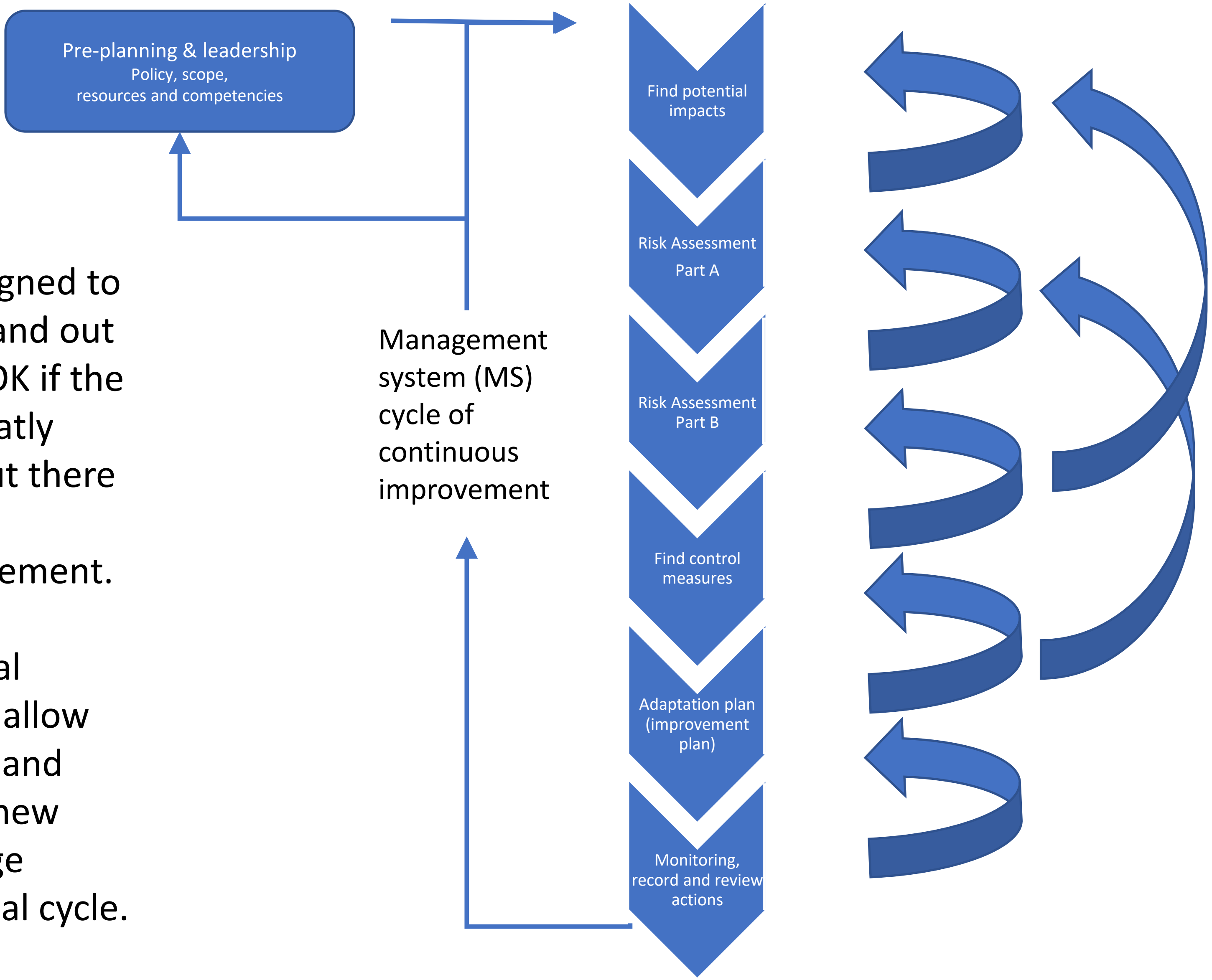


Monitoring, record and review actions

- **Monitor, record and review the adaptation plan** including monitoring of indicators which both show the performance of the management system and adaptation plan and the evolution of climate impacts vs decision trigger points
- **Monitor, record and review climate relevant data** - **(including any changes to data/assumptions)** near misses/incidents/data, both at the establishment and globally as relevant to the establishment (e.g. accident reports and weather data)
- **Identify any weather events/changes/MA knowledge that challenge existing risk assessment data/assumptions** – consider any that are significant since they could trigger early review/revision (SR and RAs)
- **Ensure top management oversight and commitment** and decisions regarding major accident risks - including **audit and review** outputs - including influence of climate change on safety at the establishment.
    - Ensure Natechs and adaptation are embedded in process safety leadership



Major hazard management system cycle - summary



ISO 14090 is designed to allow dipping in and out of sections. It is OK if the process is not neatly linear/cyclical, but there should be overall continual improvement.

The organisational approach should allow for identification and management of new Natech knowledge outwith the formal cycle.

Record & review from stage to stage and iterate as necessary as progress is made…….

…………………but don't get bogged down at one stage – top management should drive progress to meet the corporate goals for adaptation

Better to be nearly right than precisely wrong

Tim Reader

Section 3

Natech case studies

Pt.1 – Accidents that have occurred

What lessons can we learn from the past to make a safer, more resilient future?

Content

- Also, see the eNatech database and ARIA Natech and Climate Risks

Click to Return to Slide 3

Flood – Coastal acute surge/ tsunami

See also “sea level rise”

- Tsunami - a long, high sea wave caused by an earthquake or other disturbance
- Storm surge - an abnormal rise of water generated by a storm, over and above the predicted astronomical tides

- Both a tsunami or storm surge can cause abnormal sea conditions, sea defence failure and can inundate industrial sites with flooding, all potentially causing catastrophic consequences. International examples include Fukushima where in 2011 inundation of a nuclear power station by a tsunami caused loss of power, loss of cooling and a subsequent nuclear accident. Lessons from Fukushima and other Natechs have been published by IChemE. More recently, the 2022 Tonga volcano eruption caused waves that triggered a “disastrous” oil spill in Peru and the refinery operator’s emergency preparedness was immediately criticised and hundreds of Peruvians donated hair to improvise absorbent booms.

- In 2013, a UK East Coast surge caused failure of coastal defences at multiple locations. Fortunately, whilst there were no resultant COMAH major accidents, there was a severe threat to safety and significant business disruption and many lessons have been learned…
  - Lessons learned from the coastal flooding of process industry sites on Teesside and Humberside by the storm surge on 5-6 December 2013 (icheme.org)
- Another surge occurred in 2017 that resulted in more threats to industrial sites and more lessons captured in a Process Safety Forum Safety Alert.
- In the UK, the risk of coastal flooding from storm surges and high tides will increase as sea levels rise.

Flood – Fluvial/river

River (fluvial) flooding - A watercourse is a flowing body of water, including rivers, streams and brooks. During times of heavy rainfall, watercourses' capacity can be exceeded, resulting in flooding to land, infrastructure and homes. Rainfall intensity and flood extent/severity/frequency is expected to increase with the changing climate.

CSG Sandhurst: seat of fire (left) and flooding (below)

- In 2002, flooding in the Czech Republic lifted liquid chlorine tanks, damaging pipework and releasing ~90 tonnes chlorine.

Also, historic dioxin contamination was flushed into the surrounding environment, so crops and fields were damaged or destroyed (IChemE LPB Issue 180, 2004).

- It is important to recognise that natural hazards can both cause and exacerbate accidents. In 2000, a fire occurred at a hazardous waste treatment facility and three days later the site was flooded. The flooding compounded problems faced during recovery. A report of the incident and its root causes is available as case study 2 in the free to download Environment Agency special issue of IChemE's Loss Prevention Bulletin.

Flood – Fluvial/river

- Flood waters can significantly alter drainage pathways, carrying pollution over wide areas to impact people, property and the environment. Risk assessments need to recognise the full effects of Natechs to inform adequate preventive and mitigatory measures. Further guidance on flood preparedness has been published by CDOIF and on gov.uk.

Metalworking oil spill, Japan (2019)
As well as pollution, residents trapped upstairs by oil-covered flood waters reported nausea and skin irritation (Misuri et al.)

The Murphy oil spill (Hurricane Katrina, 2005) was caused when flood waters floated and buckled a large crude oil storage tank. Oil was released which contaminated people, properties and the environment and led to $330M damages.

High temperatures

High temperatures and heatwaves can cause multiple issues for industry (IMechE has discussed these for people and processes) and aggravate hazardous industrial events. A common accident scenario is fire generated by the self-heating of materials or waste. To combat fires during extreme heat, significant water resources are required.
A report on climate extremes in the UK found that we are experiencing higher maximum temperatures and longer warm spells in recent years.

In July 2019, the phenomenon was seen in France impacting industrial activities. In Cote d'Or, a fire broke out in a capacitor bank of a food-processing plant which impacted 50% of the site's production capacity. Overheating of the capacitor banks due to exceptional heatwaves was determined as the cause of the fire.

Temperatures in the UK soared to the highest the country has ever seen during the heatwave in July 2022. Due to extreme heat, conductors sagged, and transformers were overheating, leaving approximately 8,000 properties in Yorkshire, Lincolnshire and Northeast without electricity. Heat-related impacts also affected Transport and Technology sectors, leading to significant disruption.
Industry impacts that occurred affected multiple sites with fire, explosion and other infrastructure/equipment failures. Lessons from high temperature events can be explored further in French case study material – Flash 2020, Report 2020 with experience from previous heatwaves e.g. 2015 and 2012.

Wind/Storms

An increase in frequency and magnitude of storm events is possible in a changing climate in the UK, increasing threats to high hazard installations, during and when recovering from a storm. Whilst there remain uncertainties and research needs, CCC highlight that prudent planning today is vital. High windspeeds can exert strong forces on buildings, leading to damaged infrastructure, including to Net Zero solutions. Wind can carry objects that become dangerous projectiles. Furthermore, storms can cause tree fall and floods, damage power systems and lead to prolonged power outage, impacting critical infrastructure systems (including drainage & flood defence measures), causing cascading impacts and creating accessibility issues for emergency response/evacuation.

The Port of Immingham in the Humber Estuary, the UK's largest port by tonnage, was impacted by high wind speeds causing a tidal surge which breached flood defences in December 2013. The terminal is located in a highly vulnerable flood zone. The storm surge cause a 5.1m AOD river level rise which overtopped the dock entrance and filled the estate, leaving the terminal inundated by 1m flood depth. The embanked protection failed, and electrical infrastructure was badly impacted. The terminal remained inoperable during immediate recovery. In March 2017, a £7.4m flood defence scheme works was approved.

Hurricane Harvey was a category 4 storm in Texas near Houston, USA in August 2017. Home to 500 industrial sites, it is a hub for the oil and chemical industry in the US. The hurricane wiped 25% off the US' refining capacity and oil/natural gas production had to be shut down in Southern Texas. This was as a result of significant damages such as damaged storage tanks, broken pressure valves and 500 steel barrels tanks spilled oil and wastewater showing the tremendous impacts of natural and technological hazards on the environment and society. Storms bring a range of hazards – wind, flood and lightning – and unplanned shutdown/start-up risks .
See also Arkema and Biolab incident reports.

Lightning

Lightning is one of the most frequent Natech events, particularly tank fires. Infrastructure and equipment can be impacted directly by lightning strikes, such as pipes and connections, which can impact safety and electrical systems. This could lead to hazardous material releases or ignition of flammable vapours. Third party services (e.g. utilities/data) can also be impacted. There has been various research on whether climate change will cause lightning to increase or decrease, and whilst this presently remains an uncertainty there is growing evidence of increasing risk for UK.

An explosion and fires broke out at the Texaco Refinery, Milford Haven in Wales in July 1994. This accident was triggered by a severe electrical storm that caused plant disturbances in the crude distillation unit where it was struck by lightning. The explosion was caused by failure of equipment and control systems that led to a malfunction in an outlet pipe. As a result, 20 tonnes of hydrocarbon liquid plus vapour found a source of ignition and subsequently exploded.

In August 2022, a lightning bolt struck a tank at a fuel depot in Havana, Cuba which led to a fire. This spread to a second tank, causing a blast and sent black fumes into the sky. Explosions could be heard by residents. The fire left 16 dead, 121 critically injured and 1900 people were evacuated. The impacts of the disaster was compounded by an outdated energy network and fuel shortages due to increases in demand for energy during severe summer heat.

Wildfires

The CZN Lightning Complex fire over California occurred in August 2020 due to a dry lightning storm that triggered wildfires in the Santa Cruz mountains. Benzene, a carcinogen, had been detected in the water supply due to melting of infrastructural pipes releasing plastic.

There are concerns about the future of industrial plant safety and installations due to the associated risks of climate change. The interactions between hazardous industry and wildfires can cause fires, explosions or toxic spills. Without protective measures, industrial sites can be harmed as a result of thermal radiation and direct flames.

Wildfires depend on ignition, fuel and weather conditions. Wildfires are more severe during extended periods of hot dry weather.

Met Office

The Met Office's Fire Severity Index (FSI), for England and Wales is an assessment of how severe a fire could become if one were to start. However, it is not an assessment of the risk of wildfires occurring. This is used for fire prevention restrictions which aim to minimise accidental fires on access land vulnerable to wildfire.

FIRE DANGER RATING SYSTEM

Scottish Fire Danger Rating System provides similar mapping of fuel types in habitats that could lead to wildfires for Scotland.

Ice/cold

Periods of cold weather are characterised by low temperatures, sometimes combined with snowfall and/or wind. This often leads to high electricity consumption, and subsequent technical incidents. They are often the cause of power failures, disruption to telecommunication networks and a range of on-site infrastructure damage (e.g. freezing pipes or collapsing roofs). Due to a changing climate in the UK, cold days are expected to be less frequent and milder which may reduce risk. However, some have observed that this could lead to a reduction in experience responding to cold weather events and thus less effective response should it occur.

A lack of freeze protection measures was not completed in a control station of the Sunray Valero Refinery, USA. In February 2007, water in propane accumulated at the bottom of a pipe. The pipe cracked due to freezing and expansion of water but remained sealed due to ice. When temperatures increased, the ice in the pipe melted, exposing the crack and releasing 2000 kg/min of liquid propane, which ignited. The refinery was forced to shut down.

The CIA Guidance and update note on winterisation provide good information on managing process plant through severe and prolonged cold weather.

A chlorine leak from a chemical packaging company in France in 2017 from its wastewater system. This caused shutdown of the site's automatic treatment plant. The UPS system, supplying electrical power to the plant, shut down following a period of extreme cold which caused the batteries to overheat. At a later date, heated cabinets were installed in the UPS system to protect it from freezing temperatures.

Geological impacts

Not all climate change impacts are linked to acute extreme weather events. The evolution of climate and weather patterns over longer periods of time can have cascading and feedback impacts, including geological ones, which can threaten safety and environmental protection. Drought, sea level rise, subsidence, river/coastal erosion and landslips can all impact industrial sites.

Norilsk oil spill (2020) : Up to 17,500 tonnes of diesel spilled on to the ground and into local rivers. It is understood there was a combination of causal factors, including corrosion of tank bottom and collapse of foundations due to permafrost melting. The incident could cost the company over $2bn. Root causes will lie in the management system and leadership culture.

Incidents and near misses in the UK have included: Severe riverbank erosion causing washout of a site roadway and threatening a large hydrocarbon storage tank; ground movement damage to underground pipes and services; cracked bunds and drainage systems. Accidents have also occurred outside the high hazard sector where common lessons can be learned : e.g. Carmont train accident

Do net zero technologies need to be resilient to climate change?

Resilient net zero technologies

"The climate emergency and the global drive to Net Zero energy systems will require a rapid and seismic change in how energy is generated, stored, transmitted and used. Global energy policy is rapidly changing to incentivise or ensure the decarbonisation of energy systems. And at the same time, ***society must ensure tomorrow's energy systems are resilient to tomorrow's climate impacts*** *– Energy security must both* ***meet the challenges of Net Zero*** *and account for the changing climate to* ***ensure infrastructure resilience****."* Climate Change Committee, 2022

Technology that is key to achieve Net Zero such as renewable energy may be vulnerable to extreme climate and weather events.

Solar

Panels in a solar farm in Dorset were damaged during a wildfire in the heatwave of July 2022. Twenty firefighters tackled a fire at the 113-acre solar farm for three hours which had 81,400 panels.

During Storm Eunice in February 2022, one of the worst storms in the UK in 30 years, solar panels were ripped off a building roof in Southampton close to where the storm gusts were at their highest. The panels served communal areas such as lighting and elevators for the building. As a result of the storm, they were severely damaged and out of use.

Wind power

The most common cause of wind turbine fires are lightning strikes, though fires are also caused through electrical and mechanical failures, including exacerbation by high ambient temperatures.

An Australian wind turbine farm contained 112 turbines. The entire farm was shut down during a heatwave when a turbine caught on fire, leaving 63,000 homes without power. Moreover, the turbine ignited ground fires which caused burning debris, destroying 80,000 hectares of a national park. The fire was found to be caused by an electrical failure in the nacelle.

Whilst industrial sites are frequently considered as ideal locations for solar/wind, the potential knock-on risks to the establishment from blade throw or other wind-blown debris needs to be accounted for in operators' risk assessments.

Other net zero approaches are also vulnerable

During prolonged dry weather or drought, techniques ranging from carbon capture and storage to tree planting can be impacted by reduced water availability.

Floods can impact any non-resilient infrastructure – for example, flooding can impact electrical systems, and there is growing evidence of extended fire risk from Li-Ion batteries exposed to salt water.

Reservoir in drought


“Creating a net zero nation
resilient to climate change”

What are the possible failure modes from natural causes?

- Water and wind barrier failures/degradation
  - Flooding
  - Heavy rain
  - Strong winds and storms
  - Sea level rise
- Low temperature barrier failures/degradation
  - Heavy snowfall
  - Ice and prolonged cold
- High temperature barrier failures/degradation
  - High temperature and heat wave
  - Prolonged dry weather and drought
- Other barrier failures/degradation
  - Lightning
  - Hail
  - Geological impacts

How can natural hazards impact safety and environmental protection? Possible barrier failures/degradation (1)

- Flooding
  - Floating of vessels or impact damage to equipment, causing loss of containment (potential multiple losses)
  - Loss of power/utilities/control and communication systems
  - Compromising secondary/tertiary containment and drainage integrity/functionality
  - Hampering emergency response due to unavailable resources or access/egress issues
- Heavy rain
  - Sinking of floating tank roofs
  - Exacerbation the consequences of spills by providing a medium for the dispersion of the released substances
  - Compromising secondary containment capacity
- Strong winds/storms
  - Structural damage either directly or due to wind-blown debris
  - Access restrictions hampering emergency response
  - Wide area power/communications systems loss
- Sea level rise
  - Increased risk of local sea/estuary defences failing and sites flooding
  - Increased forces on jetties/coastal structures due to changes in marine/estuarine currents

How can natural hazards impact safety and environmental protection? Possible barrier failures/degradation (2)

- Heavy snowfall
  - Access restrictions hampering process operation/maintenance
  - Weight on structures causing structural collapse/loss of containment
  - Loss of power/utilities/control and communication systems
  - Compromising secondary/tertiary containment and drainage integrity/functionality
  - Flooding impacts following thaw
  - Hampering emergency response due to unavailable resources or access/egress issues
- Ice/prolonged cold
  - Freezing of process pipework causing no /low flow and associated scenarios,
  - Causing potential pipework damage and subsequent loss of containment upon thaw
  - Instrumentation faults and malfunctions leading to loss of process control
  - Metal fatigue/other equipment damage causing failures and malfunctions
  - Access issues or freezing of firefighting systems impacting emergency response

How can natural hazards impact safety and environmental protection? Possible barrier failures/degradation (3)

- High temperature/heat wave
  - Insufficient process cooling, particularly where using ambient air as coolant
  - Impact on workforce/reduced human performance
  - Process equipment/instrumentation overheating and malfunctioning,
  - Increased risk that systems may not be available when required, eg sprinkler system frangible bulb failures meaning the sprinkler system is not available on demand
  - Increased fire risk/material decomposition/ material auto-ignition
  - Increased wildfire risk (either direct impact to establishment or indirect impacts – utilities/emergency response)
- Prolonged dry weather/drought
  - Impact on cooling water or fire water availability
  - Increased vulnerability of environmental receptors
  - Subsidence/ground movement impacting on equipment supports and containment system integrity

How can natural hazards impact safety and environmental protection?
Possible barrier failures/degradation (4)

- Lightning
  - Ignition of fires at or near the installation
  - Damage to equipment, in particular, electrical and control systems
  - Wide area power/communications loss
- Hail
  - Direct impact hazard to people, plant and processes
  - Loss of power/utilities/control and communication systems
- Geological impacts
  - Impact to foundations with possible catastrophic failure consequences
  - Erosion of river/coast leading to impacts to infrastructure at or around the establishment
  - Damage to underground infrastructure, including drains and utilities
  - Cracking of containment systems

Climate impacts on industrial installations

For more, sector-specific examples of how climate impacts can affect industrial installations, see:

Adapting to climate change: industry sector examples for your risk assessment

And

Impact of Climate Change on Risk and Resilience of COMAH establishments

Click to Return to Slide 3

Section 3 continued

Natech case studies

Pt.2 – Lessons learned

What lessons have we learned from the past, and how do we make a safer, more resilient future?

Content

Core principles

- We have already seen incidents and the effects of being underprepared for climate change impacts.
- So, now what?
- We need to learn from these accidents – we need to continually improve to avoid harming lives, and impacting the environment and property
- Change stems from and is enabled by the management systems

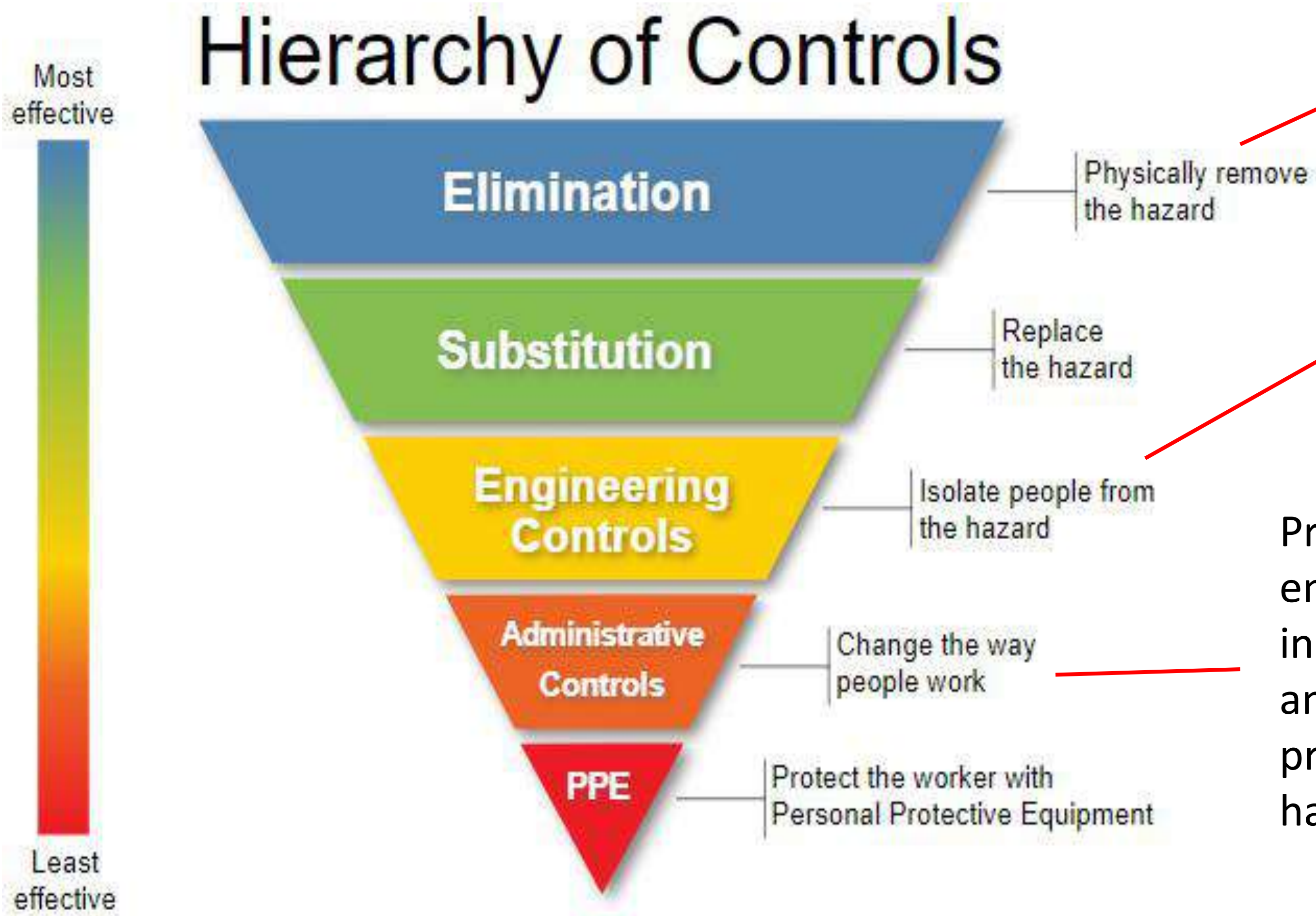
- And remember the inherent safety principle (as Trevor Kletz reminded us frequently)

- The safety and pollution hierarchies should be used to guide the choice of measures…

Introduction to hierarchy of controls

What you don't have, you can't leak (Kletz)

The safety hierarchy

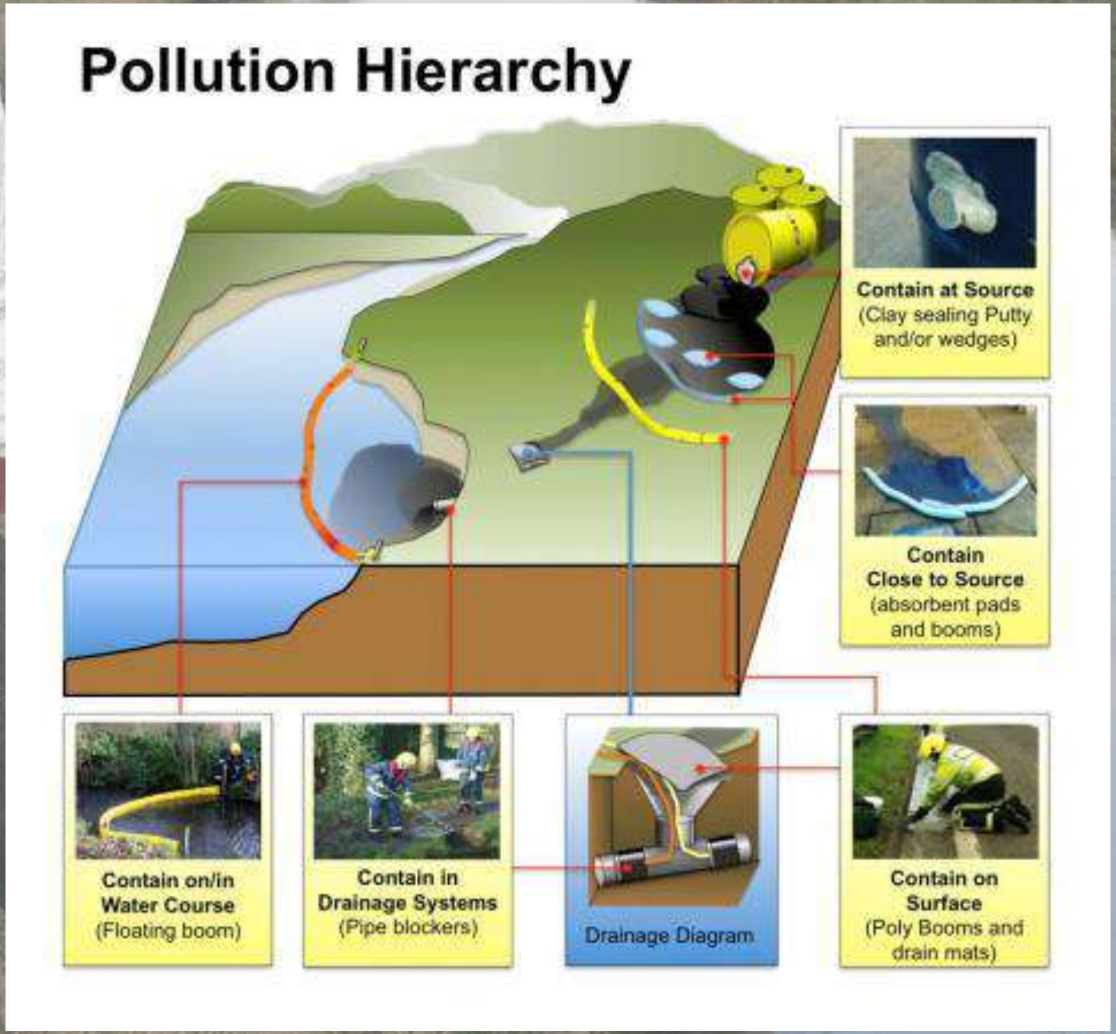


Simply removing the hazard - replacing it with something that is not as much of a hazard or locating away from the from where it could cause harm.

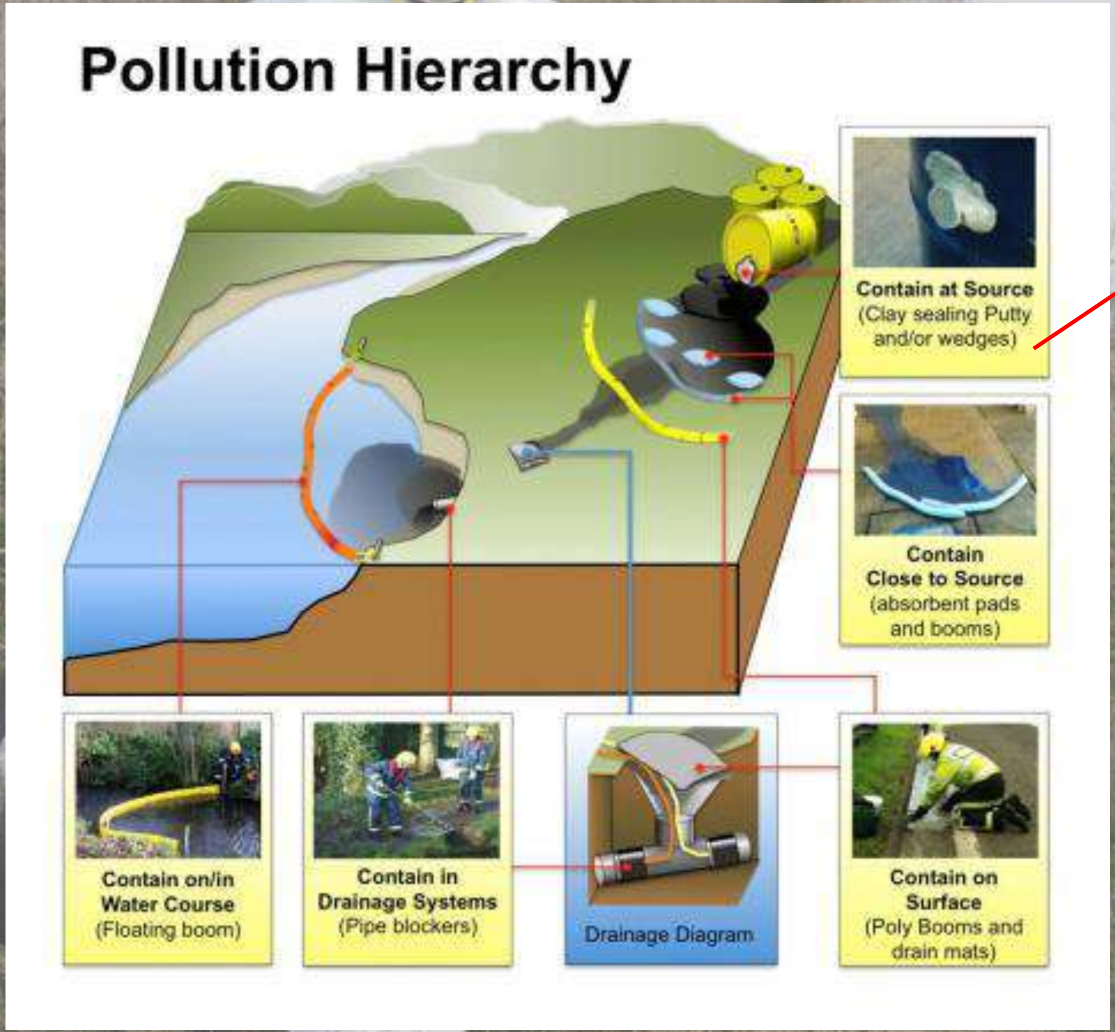
Isolate people from the hazard. The capital costs of these are usually higher than less effective control, but may reduce future costs.

Procedure changes, employee training, installation of signs and labels. Limit and prevent exposure to hazards.

Hierarchy of controls

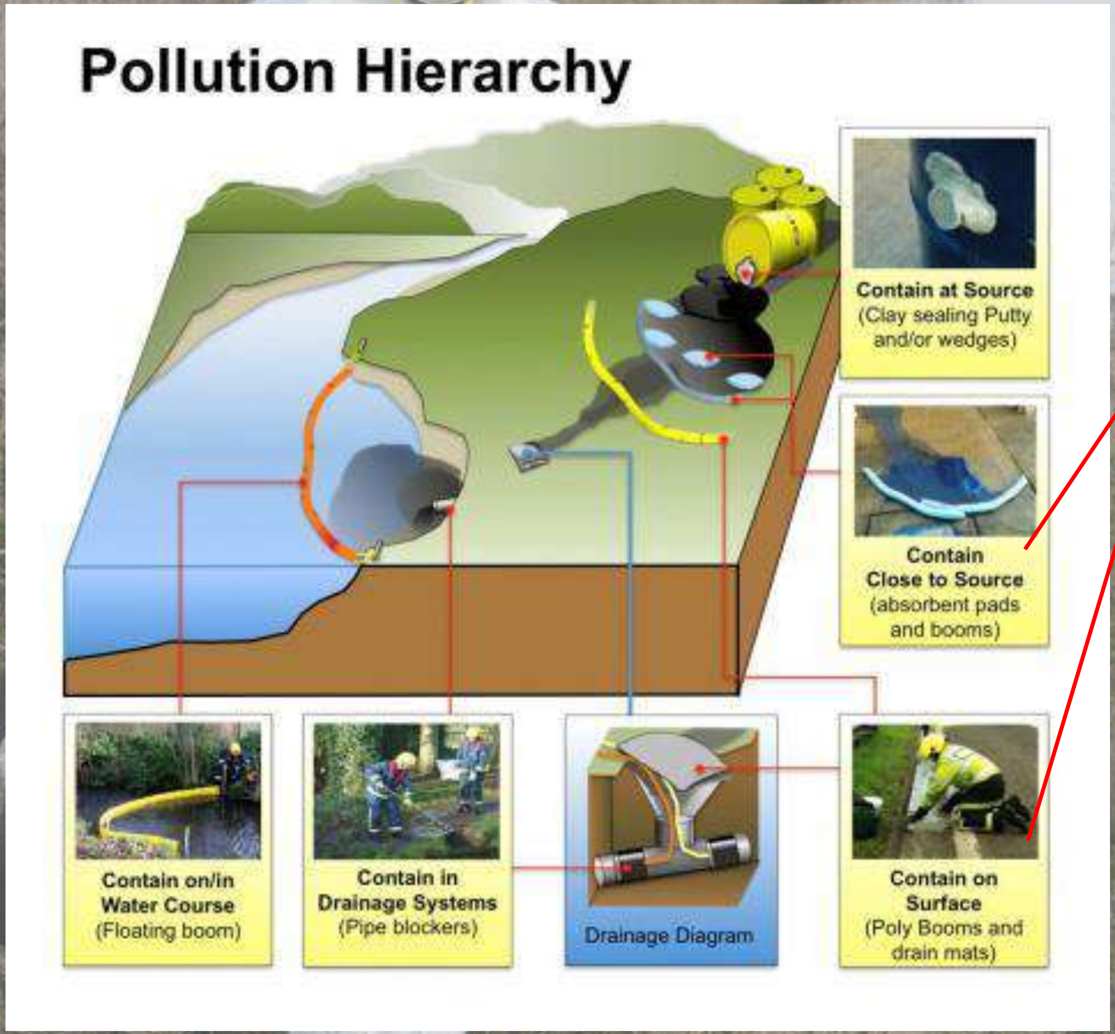


Hierarchy of controls – contain at source



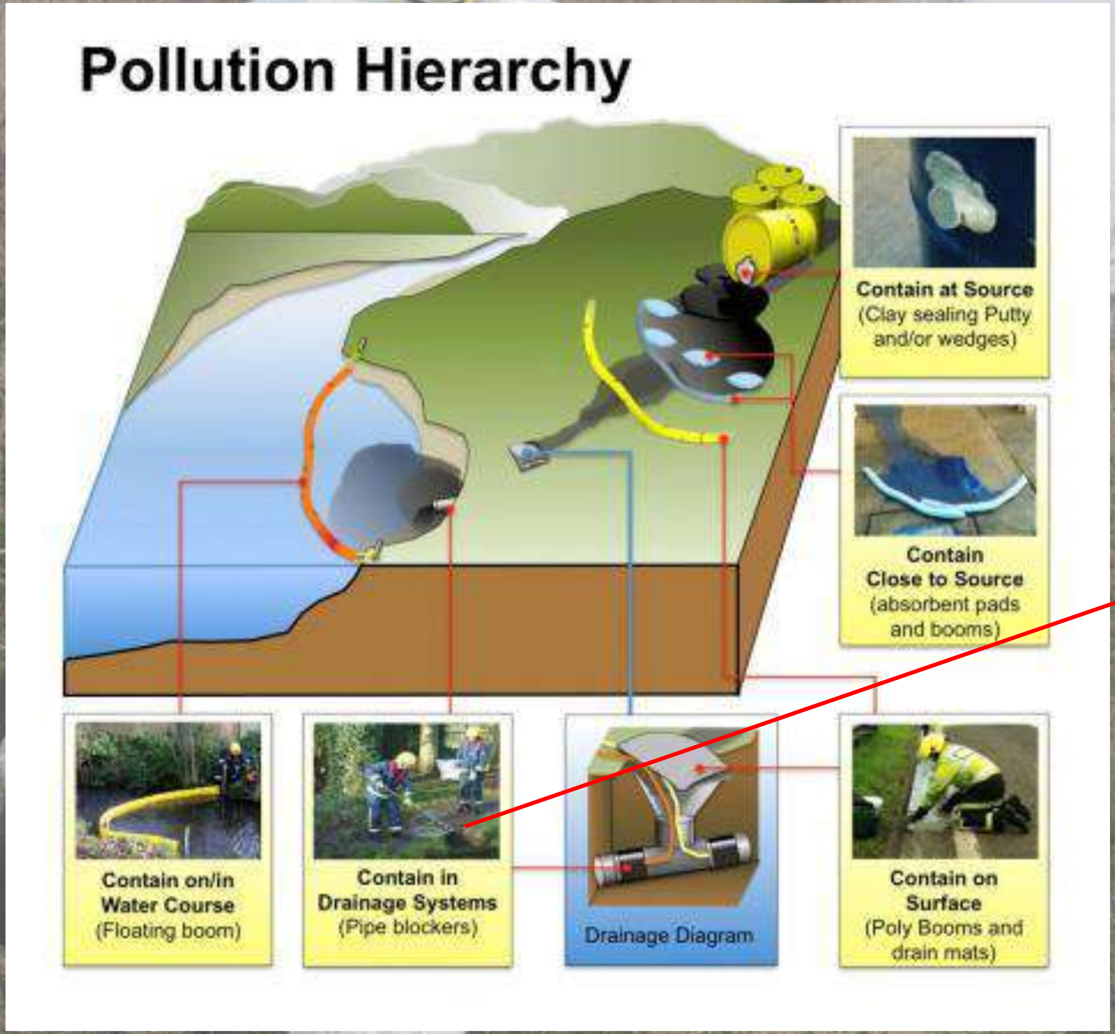
Most effective. Stop pollutant at source/point of release, e.g. seal vessel, turning mobile containers so hole is upwards, stem the flow, decant into temporary vessel, close valves.

Hierarchy of controls – contain close to source



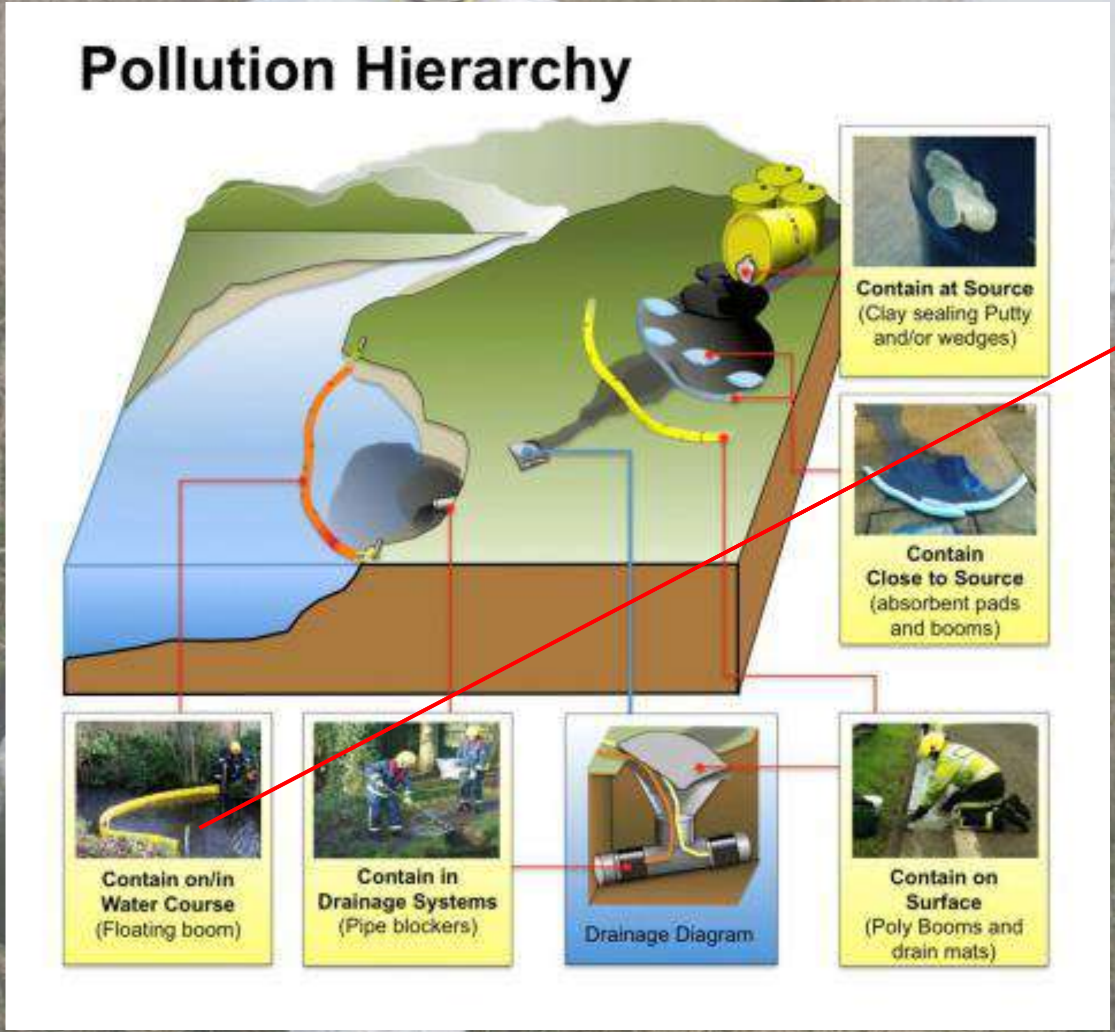
Contain the spillage as close to source as possible.
Using equipment such as sorbents, or absorbents.

Hierarchy of controls – contain in drainage system



In the very plausible case that the pollutant gets into the drainage system, there is a need to contain within the system itself before it is further distributed.

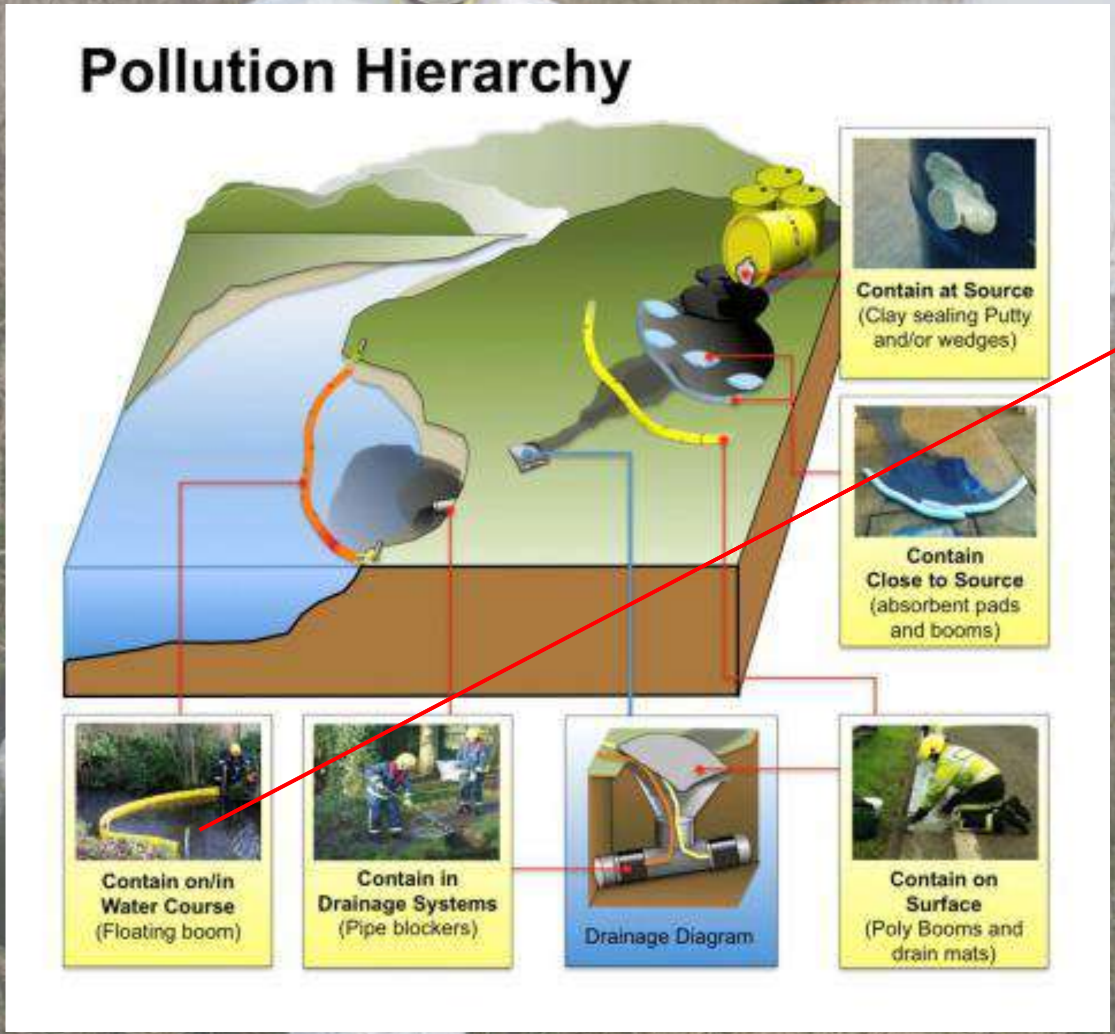
Hierarchy of controls – contain in watercource



Deployment downstream of incident can prevent/mitigate spread of pollutants less dense.

If pollutant mixes and or is denser than water, then damming is taken on.

Hierarchy of controls …



In some Natechs, like flood, none of these options may be available and risk reduction needs to focus on measures at the top of the safety hierarchy: Elimination, substitution and engineering controls for primary containment.

Deployment downstream of incident can prevent/mitigate spread of pollutants less dense.

If pollutant mixes and or is denser than water, then damming is taken on.

Key messages on learning lessons

HOW TO USE THESE PRINCIPLES AND HIERARCHIES?

WHAT KIND OF MEASURES TO TAKE?

CORE IDEAS AND LESSONS FROM OTHER SITES

ACTION NEEDED NOW TO IMPLEMENT PREVENTIONS, DON'T WAIT FOR NATECH TO OCCUR

"Following an accident, I used to say to people who've had an accident 'don't write a report, I've got it on file already'," - Trevor Kletz

There is a wealth of Natech case studies to learn from

Importance of leaning lessons

- Risk assessment sector examples – being updated to capture learning from early implementation and lessons from 2022 (due spring 2023).

- 2022 was the warmest on record for UK and brought intense heat, drought and severe storm impacts

- The greater principle is simply learning from our mistakes, learning lessons.

"Accidents are not caused by lack of knowledge, but by a ***failure to use the knowledge that is available****".*
Trevor Kletz

Lessons learned about impacts of a changing climate

News ▸ UK & World News

Today was a gamechanger says fire chief as Britain burns during heatwave

999 services now 'face a completely and fundamentally different operating environment' because of climate change

NEWS By Max Channon Overnight Editor (Live Network)
23:29, 19 JUL 2022 | UPDATED 00:23, 20 JUL 2022

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Smoke from fires being fought by fire services seen on July 19, 2022 in Wennington, England. (Image: Getty Images)

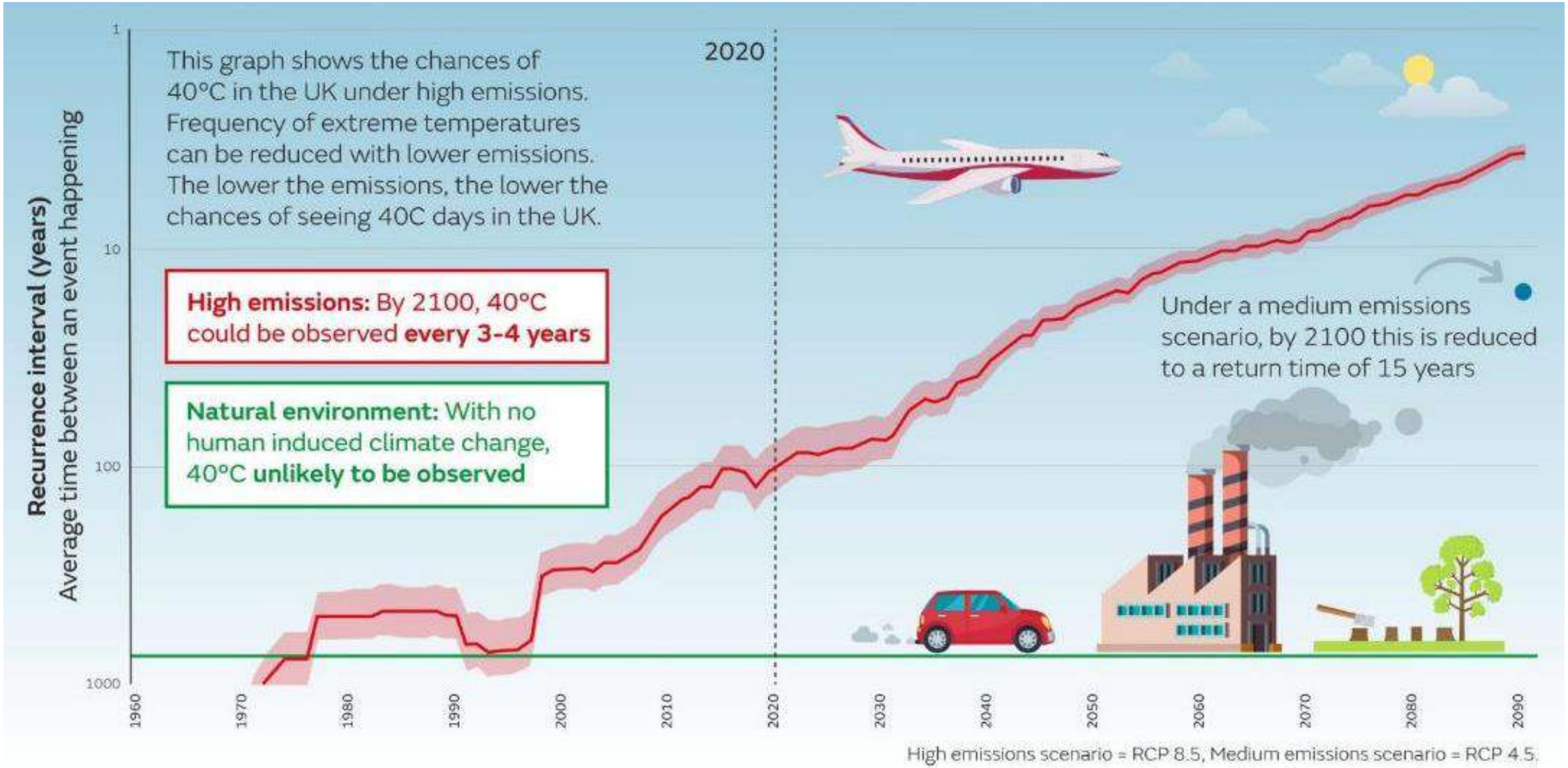
Dave Walton, a Deputy Chief Fire Officer (DCFO) for West Yorkshire Fire Service, said that he has "never known so many major incidents declared". He said this was a "peek into the future... where fires burn with such ferocity, and spread with such speed in suburban areas that you cant stop them".

"We've seen the kind of conditions faced by international colleagues just miles from our capital city, and in towns, villages and cities the length and breadth of the country," said DCFO Walton. "Today was about climate change, the hottest UK day on record - EVER!

"If you don't believe in climate change ask a firefighter who has been on duty in the last two days what they think about it."

Have emergency plans included extreme Natech scenarios? And have these been tested through operator/multi-agency exercises?

Chances of seeing 40°C in the UK under a high emission scenario



Met Office

Lessons learned from extreme temperatures

- Higher probability of a vast range of issues: over pressurisation, spontaneous combustion, overheating, melting/UV degradation of containers/pipework
- Hot temperatures shown to exacerbate many risks to do with fires and explosions
- Caused placement and exposure of equipment and waste to become very important
- Key lessons centred around management of placement of infrastructure, and flaws in design of internal systems

- Drought
  - Fires, runaway compounded by drought and strong winds
  - Increased understanding and improvement of integrated water usage and recycling systems
  - 2004 fire spread through several industrial facilities. Encouraged by ongoing drought, and a strong wind

- Wildfires
  - Management and monitoring of vegetation at the boundaries around site
  - Management of the storage of explosives and substances posing fire risk
    - How long unused/rejected substances are to be kept on site
    - Level of shade and protection from direct sunlight and extreme heat

Lessons learned from extreme temperatures

- Waste fires/scrapheap fires:
  - Management of wastes, e.g.
    - Oily rags
    - Broken and discarded batteries or engines
  - Electric batteries risks
    - Thermal runaway
    - Requires more water for extinguishing fire
  - Site management and housekeeping

- Over pressurisation
  - Disastrous chain explosions instigated on a day with temperature of 36°C, well within range of 2022
  - Heat raised temperature and pressure of gas cylinders
  - Incorrectly setup gas venting and pressure relief systems allowed for gas to unnecessarily vent during hot weather. Heated up nearby cylinders, and chain reaction allowed for spreading of fire
    - Understanding of temperature on pressure levels and thus the inbuilt systems
    - Understanding of relief systems, and constant testing and review of how they operate

Lessons learned from storms

- Storms pose a unique threat with various simultaneous impacts in combination – wind, rain/hail/snow, lightning, flood
- Recent storms have revealed a need to change how we design structures
- Key lessons learned:
  - **severe underestimation** of flood risks showing the inadequacy of existing barriers
  - **designs** of roofs and structures being unable to cope with the increasing wind loads (made worse by ageing assets)

Lightning causes gas plant fireball in Oxfordshire

17 June 2016

A food waste plant containing methane gas was struck by lightning

A lightning strike ignited methane gas at a food waste plant sending a huge fireball into the sky.

The Agrivert site at Benson, near Wallingford, Oxfordshire, was struck at about 17:20 BST on Thursday.

Commercial manager Harry Waters said lightning ignited gas stored in a waste digester, causing a fire which burned for 20 minutes and destroyed the roof.

Lessons learned from storms

- Lightning
  - Ignition of flammable substances
    - Management of wastes
    - Gases, e.g. biogas at AD sites
    - Vessels, e.g. tanks or cylinders
- Flooding
  - Floating of tanks, bunds
    - Implementation of guide rails, and connecting walkways to tanks at risk of flooding
    - Monitoring of substance levels in vessels
  - Increased conductivity for lightning throughout site

- Wind
  - Weather membranes
    - Reinforcement straps
    - Monitoring of joints and seam strength
  - Tall structures

Environment Agency Natech research

- In 2022 an Environment Agency IChemE intern researched past and recent Natechs.
- A spreadsheet was developed to break down the incidents, broadly categorising the lessons learned. This has informed revisions of Environment Agency guidance.
- In terms of lessons, the most common learnings featured at **Design and planning stage** - neglecting to consider climate change impacts from early stages of site location and design, or reviews of continuing adequacy of design, has contributed to many incidents.
- Also, failings in **Emergency Response Plans and policies** and **testing and maintenance** were frequently identified.
- All failings could have been easily improved, all fall under existing management system approaches.
- Need implementation of training and an appreciation of how climate change can capitalise on weaknesses in standard management systems.
- The agencies are training officers on Natechs, climate change adaptation and links to management system controls – operators similarly need to develop these capabilities.

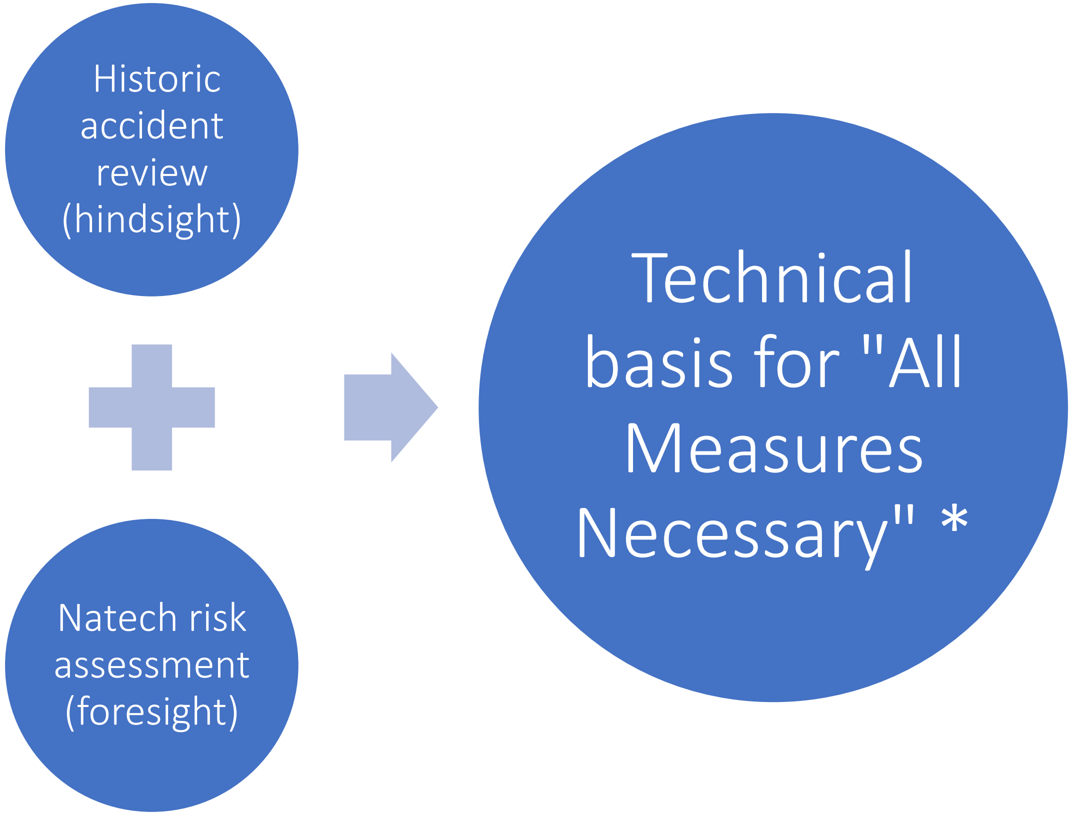
Location/Title	Date	Brief desc	Immediate causes	Underlying causes	Lessons learned	
Propane fire at refinery, Texas	2007	Liquid propane was released from cracked control station piping. There was freeze-related failure of high pressure piping. This control station had not been in service for approx 15 years. Water in propane accumulated in a low point formed by the design of station, and this froze during cold weather. This cracked the inlet pipe elbow. The ice that sealed the crack melted once the temperature rose a little, releasing a lot of liquid propane.	Pipe elbow cracked. It was sealed by frozen water, but once the frozen substance melted, propane could escape through it.	• Lack of freeze protection measures • Control station was not isolated • No management of change review when control station was removed from active service (in 90s). Freeze related hazards therefore neglected. • No shutoff valves were remotely operable. Took longer to close isolation valves to stop propane being vented to atmosphere. • API recommended safety practices for oil refineries do not include guidance on freezing, or fireproofing distance for near units w/ high pressure flammables. • Containers used chlorine to use in cooling tower. There are safer, less toxic options available. • Firewater valve too close to propane unit, so could not be opened during fire.	Freeze protection measures should be considered in management plans	35
					Appropriate isolation of dangerous units or units at higher risk of failure	35
					Isolation of decomissioned and out of service units	35
					Update review of control station once the situation changed and it was no longer in service, to evaluate new hazards	40
					Systematic maintenance to be adhered to, especially for unused/neglected equipment	19
					Valves should be designed with accessibility for operation and thorough checks and maintenance in mind	35
					Guidance for oil and flammable fuel sites should include freezing hazards	22
					Inherent safety should be applied across plant design, especially when handling hazardous/toxic chemicals	35
					Ensure fire emergency plans and equipment are feasibly placed and designed	22

No. lessons learned in category	Key *colour code*		
48	*35*	Design/early stage/planning	including location
35	*22*	Emergency response plan/policies	
18	*4*	Communication/training	
17	*15*	Secondary/tertiary back up things	
26	*19*	Testing/maintenence	
18	*16*	Underestimation/lack of consideration	
6	*40*	Management of change	
17	*15*	General direct barriers/mitigations	
7	*2*	Makeshift/short term response	

Control of accidents caused by Natech

- Natech risk can be effectively controlled by ensuring adequate management systems (root causes) that embed natural causes and climate change impacts
- The greatest opportunity to reduce Natech risk occurs at the installation planning & design stage
- Most management system aspects are important (but especially emergency planning and inspection/maintenance)
- Adequately understanding Natech risk is fundamental

➢ Generally – no new lessons!



- The extent to which risk reduction measures are adopted then depends on corporate choices – influenced by the operator's culture and safety leadership approach (and the regulator's oversight and actions)

Adaptation action in practice – cross sector examples

Under the Climate Change Act certain organisations produced reports on:

- the current and future predicted effects of climate change on their organisation
- their proposals for adapting to climate change

These reports outline good and best practices in adaptation across government and operators of key infrastructure.

The reporting information supports both national policy (e.g. the National Adaptation Programme and Climate Change Risk Assessment) and enables analysis of practical measures that can be taken to adapt.

The UK Adaptation Inventory documents adaptation on the ground, presenting a selection of sectoral adaptation options, based on national reporting to government by public and private sector organisations and a systematic review of peer reviewed literature.

https://www.nismod.ac.uk/openclim/adaptation_inventory

Final thoughts

In theory,

- COMAH, environmental permitting (and associated land use planning) can effectively control Natech risk to people and the environment…

But only if…

- Natural causes and climate change impacts, today and in the future, are embedded throughout the management system to inform operator's decisions and emergency planning.