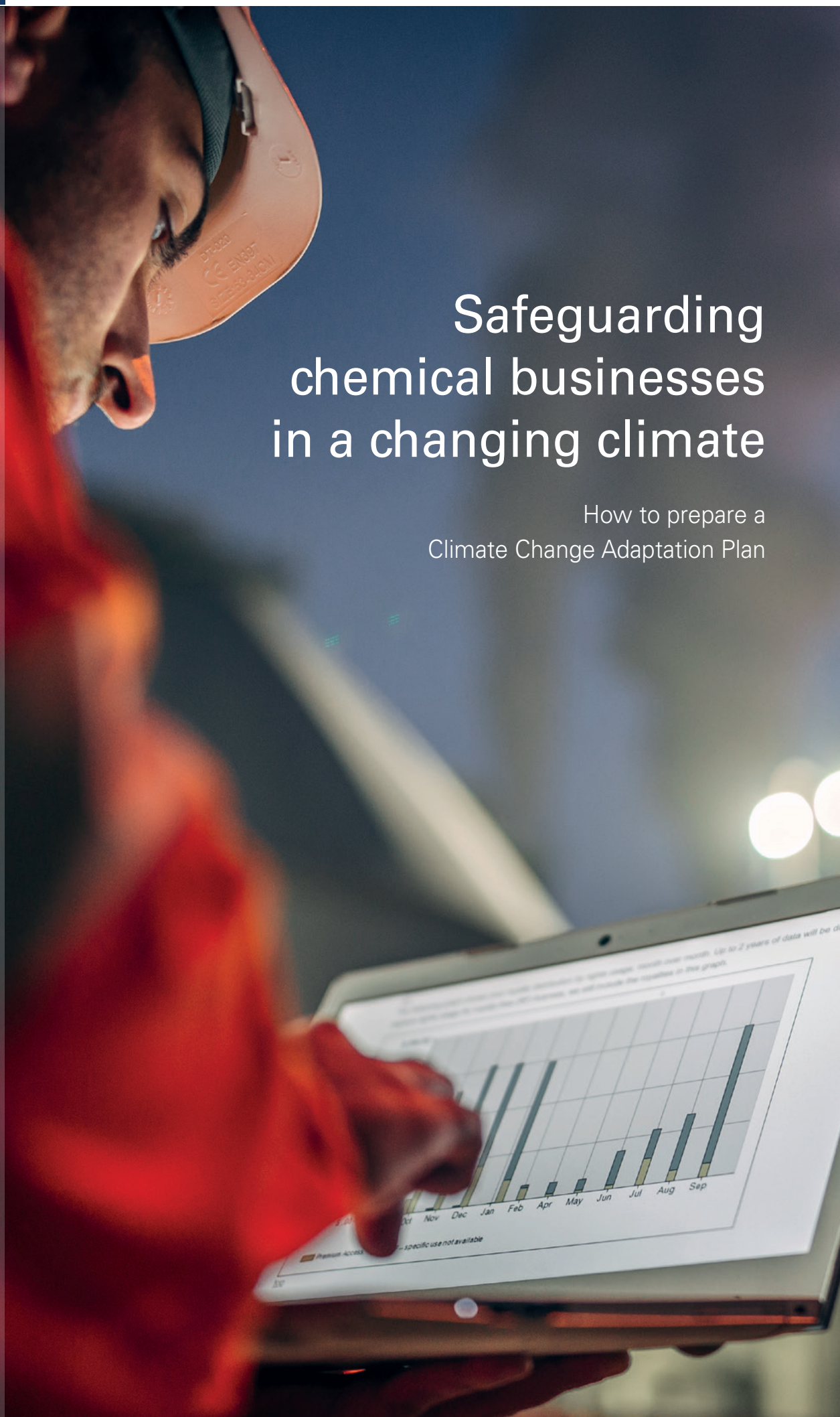
CIA

CHEMICAL INDUSTRIES ASSOCIATION

2ND EDITION

Safeguarding chemical businesses in a changing climate

How to prepare a Climate Change Adaptation Plan



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RESPONSIBLE CARE

Safeguarding chemical businesses in a changing climate

FOREWORD

As we publish this CIA guidance revision on climate change adaptation, world leaders have concluded a hard-fought agreement at the COP26 Climate Change conference in Glasgow on global national commitments to reduce carbon emissions by 2050. The COP26 consensus does not provide a final agreement that will result in limiting global warming to 1.5 degrees – the key target based on science-led projections- but it is at least deemed to be still achievable. The agreement is the first to specifically address fossil fuels and includes a welcome commitment to accelerate action and to continue the discussion involving the range of long-term lower carbon political, economic, and new technology options. Glasgow also resulted in some pledges that will make essential contributions to 'keeping 1.5 alive' if they are carried through – such as phasing down coal power, ending deforestation and reversing the decline by 2030, and a 30% reduction in methane emission. However, there were some notable absentees at COP26 and it remains to be seen whether the 'big ticket' items of Net Zero commitments by the world's largest carbon emitters will result in effective action, and in time.

Against the background of the Glasgow discussions – and those anticipated at COP27 in Egypt in 2022 – there is a much shorter-term goal that is essential for UK chemical businesses to manage: **Adaptation** to climate-related risks that are already threatening sites and will continue to do so for many years. Climate change adaptation will not only contribute to the achievement of the Net Zero targets, but at the same time protect our industry and local communities from the effects of climate change that can cause major accidents and other business disruption. A plan for climate change adaptation is needed NOW to minimize the effects on chemical businesses, with scientific evidence increasingly showing that the effects of climate change (flooding, more severe storms, drought, wildfires, supply chain disruption) are already happening, and pose immediate risks that companies need to assess and manage.

This is the focus of this guidance, developed in collaboration with our partners SLR Consulting Ltd. It has been fully revised to cover the latest UK Climate Change Risk Assessment (2021) and also the current Standards and best practice on developing adaptation plans. It aims to help chemical companies (especially those with large inventories of high hazard substances and subject to the COMAH Regulations 2015) carry out an effective risk assessment and develop an action plan tailored to each site location and vulnerability.

CIA strongly supports the UK independent Climate Change Committee's call for more effective adaptation programmes, as an essential part of the management of climate change risks and achievement of the government's Net Zero targets. The UK Climate Risk Assessment 2021 – summarised in this guidance- highlighted that all aspects of UK life including agriculture and food production, housing, transport, the natural environment as well as essential manufacturing could be adversely affected by climate change impacts. Chemical sector businesses need to take a lead to minimise the potential effects on critical chemical manufacturing and supply chains, by making adaptation and resilience of chemical facilities a high priority. CIA's guidance on adaptation is an important enabler in helping industry stay ahead of climate change impacts.

We intend to keep this guidance updated periodically to reflect new technology and shared learning developments in the fast-moving field of climate change, net zero and adaptation. We will also use it for example to advise CIA members on implications from the regulatory position on climate change adaptation for COMAH sites; this is something that is currently under discussion in some of the regulator/industry groups where we meet colleagues from HSE and the Environment agencies that make up the COMAH Competent Authority.

In the meantime, I commend the guidance to CIA member companies as a valuable tool in improving the resilience of the chemicals sector to climate-related risks. It will help maintain business continuity, manage the risks to manufacturing sites and operations, and potential impact on local communities and supply chains from extreme weather events.

Steve Elliott
Chief Executive
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In association with

SLR

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Section 1: Introduction

THE GROWTH OF THE CLIMATE CHALLENGE

When CIA first published this guidance in 2015, based at that time on the 2012 UK Climate Change Risk Assessment, it was already clear that severe weather events linked to climate change were a serious risk to chemical businesses and not just to our homes, communities and infrastructure. The effects of flooding, high winds, heatwave and drought necessitated an Adaptation plan to mitigate the worst effects. The potential consequences for many chemical and pharmaceutical manufacturing sites included major accidents with both safety and environmental impacts; supply chain disruption affecting raw materials availability and transport of finished product; and loss of business continuity due to impacts on people, plant and equipment. The CIA guidance focused on a framework to help companies risk assess these potential impacts depending on the circumstances of each individual site, and how to prepare an action plan for adaptation.

What the years since 2015 have shown is that the situation facing all sectors and all regions of the UK from climate change has got worse. Improvement in resilience and the rate of effective adaptation have not kept pace with the rate of climate change related risks. The gap between where the UK is now and where it needs to be to manage the risks is larger than it was in 2015. This bigger risk gap has implications for all sectors and all aspects of UK life – including chemical businesses. The chemical sector still needs to play its part in improving adaptation and resilience in order to protect business – people, assets and productivity – as well as managing the risk of major accidents.

From the policy and political aspect, recent years have also seen the emergence of Net Zero aspirations and targets by government. Net Zero means achieving a balance between the amount of greenhouse gases produced and emitted (strongly linked by scientific evidence to climate change), and the amount taken out of the atmosphere. The scope of this guidance does not aim to cover the ways in which Net Zero might be achieved, nor does it address low carbon technologies – it focuses instead on adaptation in the chemicals sector to minimise the impact of climate change on businesses and to protect against climate-related major accidents. However, it is relevant that in framing its 2021 Climate Change Risk Assessment and its subsequent Report to Parliament, the independent Climate Change Committee has made it clear that the evidence shows that without adaptation there is no way that the government's Net Zero targets can be met.

UK CLIMATE RISK ASSESSMENT (CCRA3)

The publication of the 2021 UK Climate Risk Assessment (CCRA3) [1] was launched on 16th June 2021. It Is the most comprehensive review of climate change impacts on the UK, and involved more than 450 experts from 130 organisations in compiling it. The report was accompanied by a separate Technical Report [2] which includes a chapter on Business and Industry.

The priorities for action identified in the risk assessment cover all aspects of UK life – risks to terrestrial and freshwater habitats; increasing flooding and drought; impact on agriculture and food production; disruption to supply chains and distribution networks; risks to people, the economy and businesses from climate-related failure of the power system; risks to human health, wellbeing and productivity; and multiple risks to the UK from climate change impacts overseas.

Because of the diversity of sectors that CCRA3 covers and the volume of evidence gathered, there is inevitably a somewhat bewildering range of information available. However, the main elements and reports are very helpfully highlighted in a dedicated new climate risk website – UK Climate Risk [3].

UK Climate Projections

The main conclusions from UK CCRA3 Reports regarding the rate of climate change in recent years and projections for the future are that:

- The world has continued to warm with effects on UK and global weather and climate becoming more evident, and increasingly attributed to human-induced climate change. Rising temperatures and sea-level rise are the clearest signals of a changing climate for the UK;
- New UK weather and climate records are being set more frequently, with the UK periodically experiencing unprecedented high temperatures and heavy rainfall;
- The UK is projected to experience ongoing increases in temperature until the middle of the 21st Century under all scenarios for future global climate change;
- The severity of extremes is projected to increase with global warming. Droughts are expected to become more severe with implications for water resource management;
- Future summers are projected to be even hotter and drier than earlier estimates from 2018 in CCRA2, for equivalent levels of global warming. We can expect more frequent and more severe extreme daily high temperatures;
- Future winter weather is projected to be dominated by more mobile, cyclonic weather systems than was the case in previous assessments. This will affect the western parts of the UK in particular, and reinforces the evidence for more substantial increases in daily rainfall with related flooding, as well as a higher incidence of strong winds and waves.

[1] https://www.theccc.org.uk/wp-content/uploads/2021/07/Independent-Assessment-of-UK-Climate-Risk-Advice-to-Govt-for-CCRA3-CCC.pdf

[2] https://www.ukclimaterisk.org/independent-assessment-ccra3/technical-report/

[3] https://www.ukclimaterisk.org/

Implications from the Environment Act 2021

At the time of publication of this guidance revision the Environment Act 2021 has received Royal Assent, and we await publication of the final consolidated Act. The Act will potentially impact water supply to some industrial sites, as the UK environment regulators will have the power to revoke certain water abstraction licences in appropriate circumstances without compensation as of 2028. Also, the water sector will have a legal requirement to have 'supply resilience plans'. Both of these could potentially impact upon the ready availability of water for industrial sites during periods of extreme temperatures and drought, and is therefore another aspect that businesses should factor into future vulnerability and risk assessments in relation to the projections for climate change.

RISKS TO CHEMICAL BUSINESS COMAH SITES

The conclusions presented in the Climate Change Committee's risk assessment and reports in 2021, and the evidence on which they are based, indicate that chemical sector businesses – like other sectors in the UK – are likely to experience periods of much higher temperatures; more severe droughts; heavier rainfall including periods of more intense rain; and stronger winds. These effects in turn can impact the safety, operational capability and sustainability of chemical businesses. They can lead to more flooding in periods of rain; less available water in periods of drought; stronger winds that might affect tall structures on sites; wildfires which we have already seen can spread rapidly and threaten industrial as well as residential developments; and loss of power or other services caused by impacts on public utilities.

Any of the above could conceivably cause very significant – even catastrophic – damage to plant, equipment, and the local environment and put people in danger. This is why it Is essential for businesses to ensure they have a comprehensive risk assessment based on the up-to-date climate change data and projections, and that this is used to evaluate the potential consequences for each site and to prioritise any Adaptation actions that may be needed to mitigate the consequences.

THE CHEMICAL CONTEXT

Weather and climate change resilience are particularly important issues for chemical businesses because:

- They are very reliant on utilities, drainage and water supply infrastructure, which can be compromised by weather events.
- Many major hazard sites store and use significant quantities of hazardous substances. Weather-related events can lead to breaches of environmental permits or trigger major accidents, with potentially serious consequences.
- On-site infrastructure tends to have long lifetimes, increasing their exposure to climate risks (because of exposure to the future as well as the historical climate).
- The industry is globalised and therefore exposed to a wide range of impacts internationally.
- These impacts include disruption to supply chains (both international and domestic) that may be caused by climate-related, political or other force majeure events affecting raw materials supply or product distribution.
- Emergency Services resources may be deployed dealing with climate change related events such as flooding or wildfires, resulting in longer response times or reduced resources able to deploy to an on site incident.
- Availability of water may be affected by both climate change and legislation.

Chemical businesses need to appreciate that as well as having effective arrangements in place to manage short-term weather-related events that can affect sites, companies need to prepare well in advance for the business risks linked to medium and longer-term climate change projections.

STRUCTURE OF THIS GUIDE

This guidance aims to help companies develop a climate change adaptation plan in order to make your business more resilient to extreme weather and climate change. Section 1 has provided some background and context to set the scene for why this is necessary and the urgency of identifying adaptations based on climate change risk assessment. The main guidance on how to do this is contained within Section 2 and draws on two ISO Standards on Adaptation to Climate Change – 14090:2019 which addresses principles, requirements and guidelines; and 14091:2021 which covers guidelines on vulnerability, impacts and risk assessment. In order to make your plan robust, the process is broken down into the following steps, which are based on current good practice and advice in the ISO Standard 14091:2021 on Adaptation to Climate Change:

Step 1 Getting started

Step 2 Identifying significant climate risks

Step 3 Managing climate risks

Step 4 Monitoring and review.

Each of these steps will be examined in turn in Section 2.

Organisations may choose to develop either a site-based or a business-wide adaptation plan. A business-wide plan will lead to a higher level of resilience, because it is likely to take into account the full range of asset management and supply chain risks from weather and climate and present a wider range of possible response measures. However, the narrower coverage of a site-based adaptation plan could make the task more manageable or focused, and is an excellent first step towards ensuring the most important actions are identified and prioritised. These actions include the risk of climate-related major accidents and regulatory compliance.

While this guidance aims to be standalone, Section 3 provides various sources of further information and advice for consideration as part of a more detailed approach to adaptation planning.

Section 4 and Appendix 1 illustrate the importance of case studies in understanding the experience and learnings from previous climate-related events in risk assessing projected future climate challenges for chemical businesses.

Finally, the Appendices and Tables at the end of the document provide example impacts, operational resilience and adaptation measures, and Templates to assist with recording the adaptation risk assessment.

Section 2: How to prepare an adaptation plan

STEP 1: GETTING STARTED

At the outset you should:

- Familiarise yourself with the ISO 14091:2021 Adaptation to climate change – Guidelines on vulnerability, impacts and risk assessment. [4] This standard gives guidelines for assessing the risks related to the potential impacts of climate change. It describes how to understand vulnerability and how to develop and implement a sound risk assessment in the context of climate change. It can be used for assessing both present and future climate change risks.
- Depending on the complexity of the infrastructure owned or managed by your business, you may also wish to consult additional guidance such as the Hydropower Sector Climate Resilience Guide, [5] which provides comprehensive guidance for climate resilience planning which can be applied to any infrastructure asset or project.
- Set broad objectives, such as to avoid potential major accidents or to maintain business continuity or productivity in the face of a changing climate (these can be firmed up later when you have more information). If your adaptation plan is to be business-wide, then these should reflect the objectives in your business plan.
- Ensure that senior management support is in place for the preparation of your adaptation plan and that the importance of business and resource decisions it may generate are clearly understood.
- Find the right people (internally and externally) to work with.
- Gather information on how your business currently manages weather risks and business continuity and on how severe weather has affected you in the past. This will help you to understand weather-related risks and highlight any vulnerabilities.
- For help considering potential risk exposures, a good starting point is the UK Government Climate Risk Assessment 2017, which looks at the main risks facing the UK, as well as the 2021 Independent Assessment of UK Climate Risk produced by the Climate Change Committee [6].
- There is also the latest Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report, which provides a set of regional factsheets [7] describing the main impacts of a changing climate. For a set of general overview slides summarising the conclusions of the latest Sixth Assessment Report please see also their official outreach slides [8].

[4] https://www.iso.org/standard/68508.html

[5] https://assets-global.website-files.com/5f749e4b9399c80b5e421384/5fa7e38ce92a9c6b44e63414_hydropower_sector_climate_resilience_guide.pdf

[6] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/584281/uk-climate-change-risk-assess-2017.pdf

[7] https://www.ipcc.ch/report/ar6/wg1/downloads/factsheets/IPCC_AR6_WGI_Regional_Fact_Sheet_Europe.pdf

[8] https://www.ipcc.ch/report/ar6/wg1/downloads/outreach/IPCC_AR6_WGI_SPM_Basic_Slide_Deck_Figures.pdf

STEP 2: IDENTIFYING SIGNIFICANT CLIMATE RISKS

Risks from severe weather and climate change can be assessed by:

- Identifying a wide range of potential impacts (such as those identified in the UK Climate Risk Assessment, by the IPCC or in the Hydropower Sector Climate Resilience Guide)
- Using a risk based approach to prioritise those that are significant.

Identifying potential impacts

Consider how the impacts of extreme rainfall, flooding, drought, temperature extremes and strong winds could affect your business. At this stage you are brain-storming, aiming for a long list without worrying about whether or not the impacts are likely to happen or would be significant.

Use the prompt questions below to think about impacts across your site or business. Think about things that have happened in the past, including near misses, as well as impacts that could become more frequent or severe as the climate changes. Also consider scenarios arising from the combination of different weather events (such as dry periods followed by heavy rain or a succession of unusually wet seasons), or those leading to widespread or prolonged disruption.

If possible, involve people with a range of experiences and an understanding of operational and business processes. If your adaptation plan is to be site-based then you may be able to miss out the final section on markets and finance.

Tables A1-A5 in Appendix 2 contain a list of examples linked to each question to aid your thinking. Note that this list is not designed to be exhaustive and there may be others specific to your situation. Your resulting list of potential impacts will be specific to your site or business and its unique circumstances. Table A9 in Appendix 3 can be used to record this.

Operations: Some chemical production processes and site management conditions are dependent on specific ambient conditions, which can be affected by the weather. For example, temperature extremes (low or high) can affect processes leading to safety excursions or reduced performance and high winds can restrict crane lifts and working at height.

Ask yourself the following questions considering both the normal operating conditions and those associated with an emergency response:

O1 – Do you operate any climate or weather sensitive processes?

O2 – Could any on site activities be affected by weather?

O3 – Could weather events lead to limits set out in regulations, policies, procedures or contracts being exceeded?

O4 – Could a weather event lead to damage to stock or other materials being stored on site?

O5 – Could a weather event have business consequences by preventing access?

Logistics: The chemicals industry relies heavily on utilities and the transport network. It is also characterised by a supply chain that has numerous interdependencies and includes many sole providers of key materials. This leaves the sector particularly vulnerable to supply chain disruption due to severe weather, leading to potential business interruption, loss of productivity or rising costs. For example, weather can disrupt in-coming and outbound deliveries due to blocked roads or difficulties at ports.

In some industries it is possible to reduce vulnerability to disruption caused by travel difficulties or loss of access by using home or remote working. However, this option is likely to be restricted for manufacturing industries since the type of work often means that employees need to be on site.

Ask yourself the following questions:

L1 – Would you be affected if weather disrupted or damaged transport infrastructure or services?

L2 – Could there be any issues arising from impacts on key suppliers?

L3 – Would you be affected if weather disrupted or damaged utilities or communications infrastructure and services?

L4 – Are any of the materials you transport temperature or weather sensitive?

Assets: Weather can cause damage, degradation and maintenance implications for your buildings, grounds, plant or machinery and there are sometimes long lead times for replacing key equipment that is compromised. For example, flooding can cause erosion of foundations and pipe supports and heavy rain can cause water to collect on stock tanks roofs, possibly causing the roof to sink allowing a loss of containment of the tank contents.

The chemicals industry uses some plant and machinery that have long lives, meaning that they will be exposed to the future as well as the current climate. Moreover, it is characterised by some ageing infrastructure and the challenges that brings.

Ask yourself the following questions, considering not just potential environmental hazards and disruption but also the implications for maintenance regimes, the design or choice of new buildings and equipment and the costs of repair or replacement:

A1 – Could your buildings be damaged by weather or climate change?

A2 – Could your equipment or other infrastructure be damaged or fail as a result of weather or climate change?

A3 – Could your grounds or the surrounding area be affected by weather or climate change?

People: Weather can affect the comfort, health and safety of employees. For example, hot weather can lead to high indoor

temperatures and thermal discomfort and high winds can lead to safety issues on site, such as working at height or damage to buildings, structures and equipment.

People who work around chemicals often need to wear personal protective equipment (PPE), which can exacerbate heat related issues such as heat stress.

Ask yourself the following questions, taking into account those working indoors and outdoors as well as off-site:

P1 – Could severe weather or climate change affect staff comfort or productivity?

P2 – Could severe weather or climate change have health and safety implications?

P3 – Could severe weather or climate change affect employees' families, homes or communities?

Markets and Finance: Weather or climate change could affect the demands and requirements of your customers, insurers and investors with implications for your business. For example, there may be an increase in demand for chemicals used in air conditioning or refrigeration and investors' perception of climate risk could increasingly affect the price or availability of capital investment.

Ask yourself the following questions:

M1 – Could climate change mean an increasing, decreasing or changing seasonality of demand for chemical products?

M2 – Could severe weather or climate change disproportionately affect your competitors?

M3 – Could climate change affect your insurance?

M4 – Could climate change influence your investors?

Prioritising risks

Prioritise only potential impacts that pose a significant risk. A simple risk based approach can be used to select these. A simple 'High', 'Medium' or 'Low' for likelihood and magnitude (in light of your objectives) is likely to be sufficient at the outset. Table A10 in Appendix 3 is a template that can be used to record this.

If there are no long term considerations, then only the current climate risk may be relevant. However, be aware that climate change that has already occurred could mean that your perception of the risk is out of date compared to the conditions at the time plant and equipment was designed or installed – and it is always worth including consideration of Creeping Change as a factor in managing risk. For any areas where longer timescales are relevant make sure you should consider future climate change.

Climate change may mean thresholds are breached in the future, even if this hasn't happened before. These thresholds can be identified from past experience, company policies, procedures or operating standards for machinery.

For each impact you have identified, ask yourself the following questions in order to assess their risk.

Likelihood

Has the impact already been experienced?

Have there been any near misses? Or are there any thresholds that are close to being breached?

Does the business area affected by the risk involve making any decisions with long term consequences (beyond 10 years)?

Magnitude

How has this impact affected you in the past?

How do the things specific to your business (e.g. the types of processes and activities, products, services, market features and available resources) influence the magnitude of the consequences?

If you are considering a future time period: are there any business or industry trends that could make you more or less vulnerable in the future?

In some cases (where the consequence could be serious or the cost of adapting high) a more detailed risk assessment may be required as a second iteration. Boxes 2.1-2.4 provide some further guidance on assessing risk, specific to each weather hazard.

BOX 2.1: ASSESSING FLOOD RISK

Flooding is the most frequently occurring natural disaster in the UK. Regulated businesses are required to prepare for flooding as part of their systems for environmental protection.

As the first step in assessing flood risk consider the following questions:

- *Is your site in an area susceptible to flooding from rivers or the sea?*
- *Is your site susceptible to surface water flooding?*
- *Has your site been flooded before?*
- *Will climate change affect the risk of future flooding?*

Use the following to help answer these questions:

- *the resources listed in section 3 below*
- *your local Strategic Flood Risk Assessment – available from your local authority*
- *your Environment Agency regulatory officer*
- *flood modelling information from the Environment Agency where appropriate*
- *a bespoke/detailed flood risk assessment where appropriate.*

BOX 2.2: ASSESSING DROUGHT RISK

Droughts occur periodically in the UK: in April 2012 drought was declared in a large proportion of England after two consecutive dry summers and winters. In England, climate change could contribute to reduced water availability in summer by reducing the amount of summer precipitation. The biggest changes in precipitation, with a reduction of about 40% by the end of the century, may be in parts of the far south of England [9]. To assess your risk:

- *Explore your sensitivity to water availability. How would you cope if, hypothetically, the amount of water available was reduced by 5, 10, 25 or 50%? The Environment Bill will give the Environment Agency the power to revoke abstraction licences without compensation from 2028, could you cope with this?*
- *Use the resources listed in section 3 to explore the water availability issues in your catchment.*
- *Check any available historical data on drought.*

BOX 2.3: ASSESSING TEMPERATURE RISK

Hot summers, such as in 2017 and 2014 will become more likely as the climate changes. On average winters are expected to become milder. However, very cold winters with heavy snow, such as we have had in recent years, will still occur.

To assess your risks:

- *Identify temperature thresholds which could affect your business (staff and processes).*
- *Check that suppliers have adaptation measures in place for extremes of temperature – would their ability to deliver/collect supplies and goods be affected?*
- *Check the UKCP18 climate change projections to see how temperatures could change. You can use UKCP18's weather generator to explore how often temperature threshold may be exceeded in future (http://ukclimateprojections.metoffice.gov.uk/). If you need help using the Weather Generator, contact climatechange@environment-agency.gov.uk*
- *Use the resources listed in Section 3 to further explore extremes of temperatures in the current and future climates of relevant locations.*

BOX 2.4: ASSESSING STORM RISK

Storms and high winds can affect businesses anvd the services on which they rely. At the moment we do not have high confidence in future projections of changes in the frequency and severity of storms and high winds. However you can assess your risk to this hazard by:

- *assessing your site to see if any areas could be vulnerable to strong winds*
- *checking if your business has been affected by storm damage in the past*
- *using the resources listed in Section 3 to further explore the potential for storms in the current and future climates of relevant locations.*

[9] https://www.researchgate.net/publication/273352204_Introduction_to_the_special_issue_on_the_impact_of_climate_change_on_water_in_the_UK

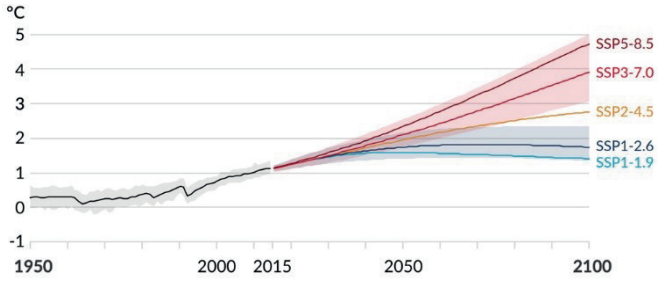
STEP 3: MANAGING CLIMATE RISKS

Once significant climate risks are known, they can be managed through an adaptation plan, which is developed through a process of:

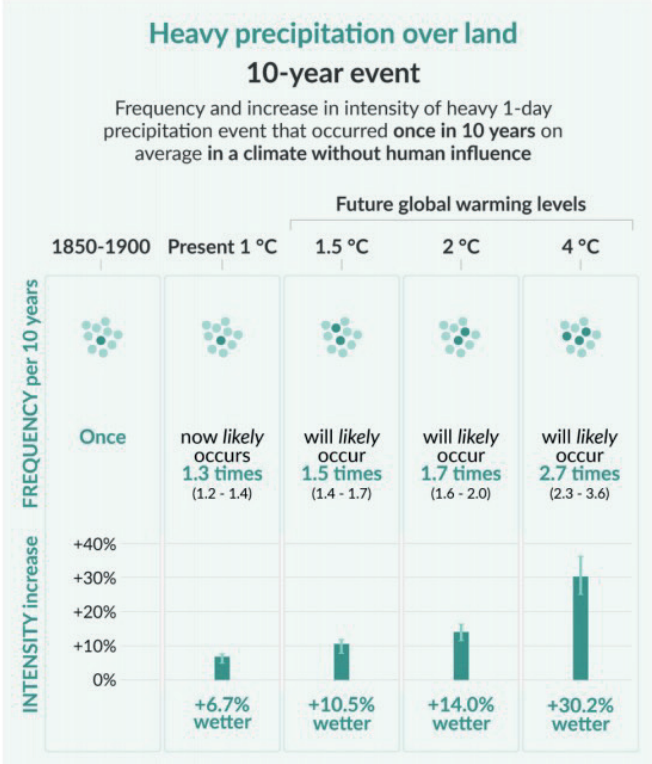
- Identifying a range of potential resilience options
- Selecting preferred measures, then
- Building these up into a plan

Consider different climate scenarios

An important aspect to consider when developing your plan for managing climate risks is to consider different climate change scenarios. Analysing different climate change scenarios is recommended by the ISO 14090 standard referenced above, and also aligns to the best practice advocated by the Task Force on Climate-related Financial Disclosures (TCFD), which is fast becoming the de-facto climate change standard for businesses. Different levels of global greenhouse gas emissions will lead to higher or lower levels of overall global heating, which in turn will impact the severity of extreme weather events. In simple terms, more greenhouse gases means more warming, which means more unpredictable and extreme weather to plan for.



The IPCC uses what it calls 'Shared Socioeconomic Pathways' to develop potential temperature scenarios. SSP5-8.5 is the highest warming pathway, SSP3-7.0 the second highest and so on. The IPCC Sixth Assessment report also provides an indication as to how different temperatures impact the likelihood and severity of different climate impacts. Please see the following Figure for an example looking at how heavy precipitation over land can be influenced by higher temperatures.



Selecting climate scenarios

From a risk management point of view and because the most recent data suggests that we are tracking the highest emissions pathway [10], and therefore the highest warming pathway, it makes sense to consider at least one high-emissions scenario with the most severe weather-related impacts. For businesses considering 'transition risks', that is risks associated with the transition to a low carbon economy such as increasing regulation, a helpful scenario to consider is what the Bank of England refers to as a 'late action' scenario where actions to mitigate climate change are taken but they are delayed and therefore when they are introduced they have to be more severe. For example, carbon prices can be expected to be far higher in such scenarios increasing costs related to fossil fuel usage.

Using forward-looking downscaled climate change projection data to fully identify risks

As recommended by the ISO 14090 standard, forward-looking downscaled climate change projection data can be used to enhance understanding of how climate change will influence specific weather variables in a particular location. 'Downscaled' means recalibrating global or regional models climate models to focus on smaller scales. Depending on the variables chosen, data is often available at the resolutions of 5km x 5km grid squares, or even more granular in some cases. This data can be more useful for planning than generalised datasets covering larger regions such as 'the UK' or 'Northern Europe'.

[10] Christopher R. Schwalm et al. PNAS 2020;117:33:19656-19657

As stated in the ISO 14090 standard, it may be advisable to seek external advice or data from expert practitioners with the relevant knowledge of climate change scenarios and downscaling.

Identifying resilience options

For your priority risks, brainstorm potential ways that you could minimise the threat or maximise any benefit, if possible involving others from across the business.

Ask yourself the following five questions, drawing on: experience of dealing with similar risks; from what you know about how others manage similar risks; existing related plans such as business continuity plans and accident management plans, as these may already contain suitable resilience measures. Consider both permanent and temporary arrangements as well as measures which would benefit from working in partnership (such as with other companies on the same industrial park) to share costs, other resources, information or learning.

How could you improve resilience generally by targeting the business consequences of incidents (e.g. disruption, costs or reputation)? See A5 of Appendix 2 for examples.

What information, awareness or skills would improve your resilience to your priority risks? See table A6 in Appendix 2 for examples.

What operational changes could you make to manage your priority risks? See table A7 in Appendix 2 for examples.

What physical changes or technology could you invest in to manage your priority risks? See table A8 in Appendix 2 for examples.

Due to the nature or size of the risk or opportunity are there any strategic responses that should be considered, such as by relocating, developing a new product, exploiting a new market or creating a strategic partnership to manage shared risks?

Selecting preferred measures

Once you have identified a list of potential options, you should evaluate these in order to choose preferred measures by asking yourself the following questions.

Will it work?

How much will it cost?

Will there be any unintended consequences for you and/or others?

Is it flexible enough to allow for adjustments later on? For example you might choose to build a flood wall now, but build larger foundations to allow it to be raised at a later date if necessary.

Is it practical to implement within relevant timescales?

Making a plan

Your adaptation plan should set out what you intend to do before during and after a weather event and when it is appropriate to implement any pre-emptive measures and those aimed at exploiting opportunities. It should be clear who is responsible for implementing actions and for monitoring and reviewing the plan.

Take note of links to other plans and procedures, such as business continuity management, risk management, health and safety arrangements, emergency plan and/or flood plan. You might choose to have a standalone adaptation plan which references other appropriate plans, or you might find that all measures can be more effectively implemented through other plans. Either way, ask yourself the following questions in order to build your selected resilience measures into a coherent plan.

What are the timescales of associated business decisions? For example, the lead in times involved in contingency arrangements when supply of key ingredients is disrupted.

For any future risks, can you estimate when it is likely to become significant?

Are there any points in time that represent an opportunity to put in place physical resilience measures that have a cost associated with them in a cost effective way? For example, within replacement cycles, maintenance regimes or management system review schedules.

What barriers to action are there likely to be? And what capacity building could help overcome these? See table A6 in Appendix 2 for examples.

Do you need to do any external engagement to make sure that your plan connects with the arrangements of neighbours, suppliers or others as appropriate?

STEP 4: MONITORING AND REVIEW

Making sure an adaptation plan works requires

- Monitoring weather impacts and the effectiveness of measures
- Exercising the plan and
- Reviewing it regularly

Monitoring weather impacts and effectiveness of measures

You should record weather impacts that have an effect on your business noting the effectiveness of your planned measures (see Appendix 3 for template). This will give an indication of the extent to which your plan is achieving the objectives set out at the beginning and managing your priority risks. The information gathered can also be used to check assumptions made in your assessment of risk.

Exercising

Make sure plans for dealing with incidents are regularly exercised. It is worth exercising scenarios that involve a combination of different events at the same time or in quick succession or scenarios related to widespread disruption.

Regular review

The output of monitoring and exercising should feed into a review of your plan. You will need to decide how often the plan will be reviewed and who will be responsible. These reviews could coincide with scheduled reviews of the other business systems. We recommend you review your plan annually or sooner if a factor that has influenced your objectives or assessment changes significantly, for example, if new information becomes available either in the form of published climate information or your own experience of a severe weather event.

Section 3: Sources of further information and advice

Guidance for the chemicals sector on potential impacts and mitigation measures

In October 2021 the Environment Agency published information for the chemicals sector of climate-related impacts and mitigation measures to consider when preparing climate change risk assessments.

The guidance covers potential impacts from summer and winter maximum temperatures; extreme and average projected rainfall; and the effects on sea level rise, river flows, and from drier summers. The guidance is available here: https://www.gov.uk/government/publications/adapting-to-climate-change-industry-sector-examples-for-your-risk-assessment/chemicals-examples-for-your-adapting-to-climate-change-risk-assessment

Climate projections

- UK Climate Projections http://ukclimateprojections.metoffice.gov.uk/

Weather extremes

- For information on weather extremes in the current climate: https://www.torro.org.uk/extremes
- For information on future weather extremes https://www.ipcc.ch/report/managing-the-risks-of-extreme-events-and-disasters-to-advance-climate-change-adaptation/changes-in-climate-extremes-and-their-impacts-on-the-natural-physical-environment/

Flooding

- General information on preparing for flooding, including access to the Environment Agency's flood maps https://www.gov.uk/prepare-for-a-flood
- The relevant Catchment Flood Management Plan – https://www.gov.uk/government/collections/catchment-flood-management-plans
- To register for flood alerts – Floodline – 0345 988 1188 or visit https://www.gov.uk/sign-up-for-flood-warnings
- Preparing for flooding: a guide for regulated sites https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/439863/LIT_7176.pdf
- Pollution prevention guidance https://www.gov.uk/guidance/pollution-prevention-for-businesses
- Living On The Edge explains the rights and responsibilities of riverside ownership https://www.gov.uk/guidance/owning-a-watercourse#manage-flood-risk-rules-and-responsibilities

- CIRIA Report 736 'Containment systems for the prevention of pollution' https://gptenvironmental.co.uk/application/files/7815/0047/9511/CIRIA_report_C736_-_Containment_systems_for_the_prevention_of_pollution.pdf

Drought

- The Catchment Abstraction Management Strategy (CAMS) for your area, which show water availability for each river catchment: https://www.gov.uk/government/collections/water-abstraction-licensing-strategies-cams-process
- The latest River Basin Management Plan for your area to find out if catchments in your area are over-abstracted from the point of view of the water environment: https://www.gov.uk/government/collections/draft-river-basin-management-plans-2021
- Further information on drought can be found here: https://www.gov.uk/government/publications/2010-to-2015-government-policy-water-and-sewerage-services/2010-to-2015-government-policy-water-and-sewerage-services
- Cefic's 'Water Matters' initiative aims is to define sustainable water management metrics indicators. Look out for these in future Responsible Care and Cefic Sustainability reports.

Temperatures

- Health and Safety Executive's information on work place temperature requirements: www.hse.gov.uk/temperature/index.htm

Further resilience/adaptation/emergency planning resources

- HSE's Emergency Planning for Major Accidents: COMAH http://www.hse.gov.uk/pubns/books/hsg191.htm
- The business resilience healthcheck is an online questionnaire that results in a report recommending actions. Looks at resilience more broadly than climate risks: https://businessresiliencehealthcheck.co.uk/
- 'Assessing and managing climate change risks in supply chains' provides information on climate risks and opportunities, and guidance on how it can be integrated into established business practices for addressing risk across supply chains. Includes five case studies: http://www.asocam.org/sites/default/files/publicaciones/files/7e9e41ffd0a419ca4a7cecc796cdfcee.pdf
- 'Adapting to Climate Change through your business continuity management system' is aimed at business continuity professionals and is compatible with the current ISO standard on business continuity management: https://www.bsigroup.com/localfiles/en-gb/iso-22301/resources/bsi-sustainability-report-adapting-to-climate-change-using-your-business-continuity-management-system-uk-en.pdf
- The 'Adaptation Wizard' is a generic and comprehensive guide to the adaptation process presented in five steps with signposts and templates for each: https://www.ukcip.org.uk/wizard/
- The Institute of Environmental Management and Assessment have produced guidance on building support for climate change adaptation in an organisation: https://www.iema.net/resources/reading-room/2020%6/26/iema-eia-guide-to-climate-change-resilience-and-adaptation-2020
- The Ofqual accredited 'Get Resilient' training course involves developing a resilience plan for your own business: https://sfediawards.co.uk/level-3-award-in-understanding-and-planning-business-resilience-survey/

Section 4: Case studies

Case studies illustrating the experiences (good and bad) from the impacts of climate-related severe weather events can be extremely valuable in helping with the approach to an effective risk assessment for adaptation actions. A short description of 'real' incidents show us that the projected effects of climate change are not simply theoretical – they represent the practicalities of how sites can be affected and some of the learnings to implement in order to mitigate the consequences.

In Appendix 1 a number of short case studies are presented, covering:

– Cumbria Flooding 2015;

– Wildfires in the UK;

– Teesside Flooding December 2013

There is also a section on 'Learning lessons from International cases', including:

– California Wildfires 2020;

– European Heatwave 2019;

– Arkema Chemical Plant Fire in USA;

Inevitably as the effects of climate change are already happening both globally and in the UK, the impacts on manufacturing businesses of severe weather events that would have benefitted from better adaptation are becoming more commonly seen in news media. CIA will update this aspect of the adaptation guidance, including success stories of where adaptation resulted in a positive outcome, as we learn of such examples.

CUMBRIA – FLOODING

In December 2015, Storm Desmond set a record, with 341.1 millimetres of rain falling over a 24-hour period which caused detrimental effects across the UK, but especially across the North West of England.

Over 43,000 homes across Cumbria and Lancashire suffered from power cuts and approximately 5200 homes were affected by flooding, 40 schools within Cumbria were also forced to close due to lack of power supplies.

The estimated cost of the flood was £500 million across Cumbria.

The flooding was so severe across the county that authorities in Cumbria declared the flood event as a 'major incident'. Around 350 army personnel, along with fire and rescue services from other areas of England were drafted in to help with rescues, evacuations and building temporary flood defences.

Three bridges in the county were washed away and a further 14 bridges were damaged and closed until further assessment could be carried out, leading to accessibility issues across the region. Flooding across Cumbria and Carlisle caused disruptions to the main railway line between London and Glasgow, leading to major transport disruptions across the UK.

The region's power network operator Electricity North West spent £7.9 million on flood defences to protect its substation infrastructure against extreme flooding, following the 2009 flood events. However, these flood defences were ineffective in tackling the flooding which occurred in December 2015, as a result the Caton Road substation was flooded which left tens of thousands of households and businesses with no power.

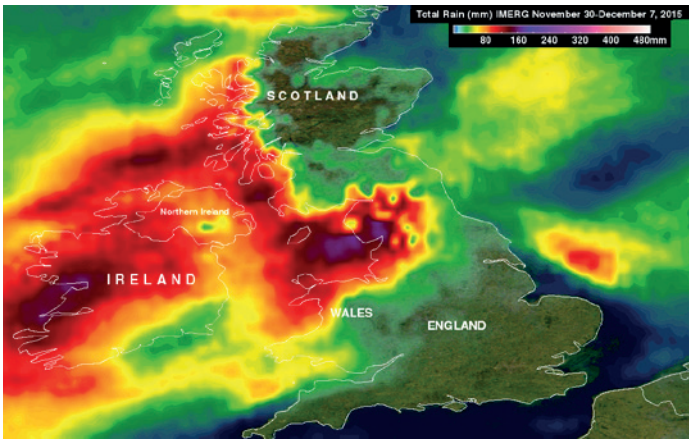
Source

https://floodlist.com/europe/united-kingdom/storm-desmond-floods-cumbria

https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/weather/learn-about/uk-past-events/interesting/2015/flooding-in-cumbria-december-2015---met-office.pdf

https://www.lancasterguardian.co.uk/news/weather/lancaster-power-hub-battered-storm-desmond-2015-gets-ps57m-revamp-1250342

https://www.zurich.co.uk/-/media/project/zwp/united-kingdom/docs/external-links/perc-report-uk-2015.pdf



WILDFIRES – UK

Incidents of wildfires are becoming increasingly common in the UK as the country experiences hotter and drier weather conditions linked to climate change. In 2018, the Moray wildfire raged for over two weeks in northern Scotland. There were 80 firefighters, 19 fire engines and two helicopters battling the fire at its peak, across four different fronts. The fire destroyed over 25 square miles of grassland and peat. This is considered to be one of the largest wildfires that the UK has seen in recent years.

Not only are wildfires becoming more common across the UK but also across Europe. According to the European Forest Information System which monitors wildfire activity for the European Commission, there were 137 fires in 2019, up from 79 fires in 2018.

There are further examples of wildfires in the UK in recent years, for example, during a mini heatwave in April 2020, the warmer weather caused wildfires in North Wales as well as the Peak District.

Although UK wildfires have so far not had the same level of devastating effects compared to those experienced in Australia, California and countries in southern Europe they still have an impact as they damage ecosystems, destroy buildings and property, and remove firefighters from their normal duties. As wildfires are predicted to occur more frequently there are concerns that emergency services will be stretched as they try to cover their usual duties as well as tackling extensive and long-running wildfires. It is important that chemical business sites – depending on their location – now include the potential vulnerability to the effects of extensive forest and moorland wildfires and spread of smoke, as part of their climate change risk assessment.

Source

https://www.nationalgeographic.co.uk/environment-and-conservation/202%4/british-wildfires-are-getting-more-frequent-heres-what-that

https://www.newscientist.com/article/2272127-wildfires-could-become-a-big-threat-in-the-uk-due-to-climate-change/

A firefighter confronted by a wildfire in the Highlands (johnogroat-journal.co.uk)
Credit: Gary Anthony

TEESSIDE FLOODING DECEMBER 2013

Due to a combination of high tide and storm surge, December 2013 saw record breaking flooding on the East Coast. In Teesside, two separate flood defences failed, one of which was an operator's own defences at the head of the River and the other was the Environment Agency (EA) maintained flood defence on Greatham Creek. Many more flood defences were overtopped and flood waters were recorded as high as 4.08m affecting several industrial sites, including chemical facilities.

There was no loss of process containment, however, the flood led to millions of pounds worth of damage and disruption. Initial confusion over the ownership of one of the flood defences, took up valuable time at the early stages of the incident. When there are only 12 hours between high tides and with facilities requiring up to two hours to be shut down properly, time is of the essence.

During the flood, the EA were able to take action to help the operators to mitigate the consequences of the flood, including: mobilising resources the day after to start work at Greatham Creek; allowing the Riverside Terminal to over pump flood water back into the River and providing advice on where to find clay. Afterwards, the EA and the Health and Safety Executive took a pragmatic approach to their role as the Competent Authority, relying on inspection to ensure safe systems were being adopted rather than formal modification reports and assessments.

ABOVE: Inter Terminals, Riverside Terminal. Water overtopping the flood defences – as seen from a ship at the terminal. BELOW: SABIC Brinefields and Cavities storage area showing the flood defence breach. © Environment Agency

Below outlines how the flood affected three facilities in the area. All of these sites had flood plans, which were enacted and the experience suggests that the costs would have been far greater had they not.

Facility 1: A chemical storage terminal

This storage site was completely flooded to the point where eight of their ten bunds were overtopped and with empty stock tanks floating in water. In response, the site had to be shut down with product still in tanks and transfer lines.

This shut down meant that their principle customer was restricted to 30% of capacity, representing a real financial loss at a time when demand was not a limiting factor.

Since the flood level was above the electrical switch house roof, all electrical and control systems were lost and the main switchgear and control PLC needed to be replaced. This meant that although limited manual operations were able to start a week later, it will be months before the terminal is back to normal.

Whilst the recovery was ongoing there was also the issue of protecting the site from the next spring tide in January (in the face of seriously compromised defences), which was only just achieved.

Facility 2: A large petrochemical plant

As the plant flooded, all field instruments and 415V electrical systems were taken out, however, 11 kV and central instrument function were not affected. Underground storage facilities at the site were flooded. Product storage systems had to be shut down, again with product in transfer lines, as did a natural gas processing plant due to condensate lines being under water. The storage facilities only came back into service fully in April 2014, 4 months later.

Since interplant buffer storage of hydrocarbons was not available, dependant plants were operating 'just in time' for most raw materials. Due to the size of the plant, national gas supply integrity was affected.

The cost of the flood to the business, including restorative work, ran into millions of pounds. The operator used established major overhaul management systems to manage the restoration work in a systematic way.

Facility 3: A third 'Top Tier' COMAH site

The operator of this facility had not registered the site address for flood warnings from the EA and therefore they only had about half an hour's warning, given by the Local Authority Emergency Planning Unit. They shut down all operations involving gas and the site boilers and took a roll call but were not able to evacuate the site before the flood cut off normal access to the establishment.

Subsequent site evacuation was 'Ad Hoc' and all site based employee's domestic cars were written off. Due to water ingress into an old PLC control system, one workshop was rendered inoperative. However, limited operations restarted two weeks after flood.

Lessons learned

- Flood defences can fail
- Putting in place a flood plan is essential
- Operators should register at their actual address for flood warning purposes, not the communication address or head office
- Operators must know who owns and maintains flood defences that they rely upon
- Early communication with the EA during flood events can help both parties in a number of ways, even where there are no regulatory issues

The storm surge of 2013 is classed as the worst natural disaster Britain has experienced in the 21st century. The extreme weather event has highlighted the vulnerability of the east coast of the UK to flooding events which may become more frequent due to climate change.

As extreme weather event such as flooding increase, the UK is in a constant battle to protect homes and livelihoods from devastation. Yorkshire is a prime example of an area of the UK which is overwhelmed by flood risk and continued flood management. In 2019, parts of the Yorkshire Dales experienced flash flooding which caused disruption to local communities as key infrastructure such as bridges and roads were damaged. The flood was described as 1 in 100-year event and clean up from the incident took weeks.

In January 2019, the East coast of England received further flood alerts as fierce storm winds and high tides hit this vulnerable part of the UK. Further in June 2019, heavy rainfall occurred throughout the North of the UK, with parts of Lincolnshire receiving 2.5 times the monthly average rainfall across 3 days. This highlights the continued vulnerability that the East coast of the UK has in experiencing severe weather events which will only become more frequent due to climate change.

Learning lessons from international cases

CALIFORNIAN WILDFIRES – 2020

During the summer of 2020, 4.2 million acres burned across California, releasing 112 million tons of greenhouse gases, requiring 11 million gallons of fire retardant to be used. The wildfires destroyed over 10,000 buildings and killed 31 people. Some fires were still burning four months later.

On the weekend of August 15th, 2020, a storm hit Central and Northern California. Instead of providing much needed rainfall in the already dry landscape, during the electrical storm the skies were lit up with more than 15,000 lightning strikes, which sparked numerous fires. The dry storm was followed by warm winds, fanning the fires in various directions.

The volume of incidents challenged available resources and immediately strained the California mutual aid system. California made 935 requests for assistance; only 193 were answered, due to a lack of crews and equipment as neighbouring states were tackling their own wildfires.

By mid-August 14,000 firefighters were working in California. Although an astonishing figure this was still not enough – at the height of the crisis 18,500 firefighters battled blazes across California.

Fire services from across America and internationally from Mexico, Canada and Israel eventually provided support to the Californian firefighters who had been fighting the wildfires for weeks without a break.

It is estimated that the 2020 Californian wildfires cost the state emergency fund more than $1 billion.

One of the deadliest fires of the summer of 2020 in California was the North Complex which claimed 15 lives, burning 318,000 acres, and destroying nearly 2500 structures.

Not only were emergency services from within the state of California stretched to tackle the fire, but neighbouring states were also unable to offer support as they battled wildfires themselves. It is clear to see that the emergency services of California were completely overwhelmed by these events which are set to become more frequent due to climate change. In addition, as the emergency services turned their attention

The Hennessey and Spanish Fires burn towards Lake Berryessa on 18 August, 2020
Credit DAKennedy (Wikipedia)

to the wildfires, it questions whether they were able to address other emergency incidents across the state.

Sources

https://calmatters.org/environment/2021/07/california-fires-2020/

https://www.theguardian.com/us-news/2020/dec/30/california-wildfires-north-complex-record

EUROPEAN HEATWAVE 2019

In July 2019, the UK experienced record-breaking temperatures as a heatwave consumed Western Europe. The city of Cambridge, saw a temperature of 38.7 degrees Celsius which at the time was the UK's highest daily maximum temperature ever on recorded.

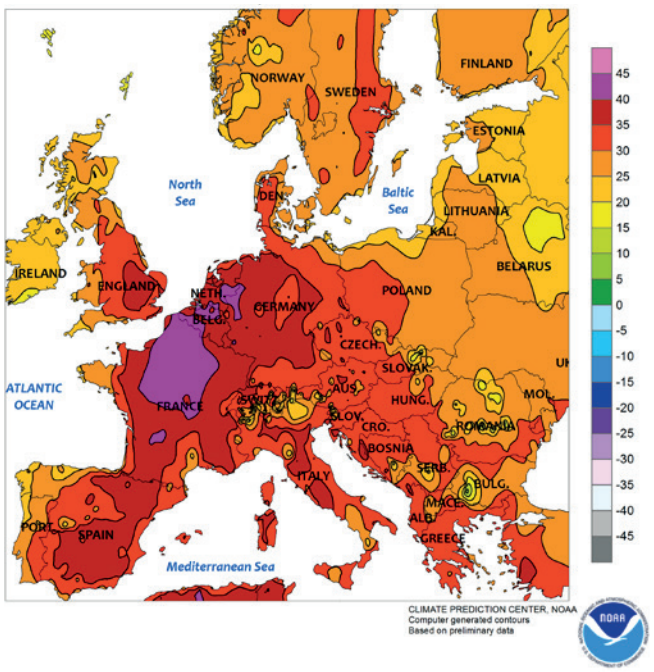
A study carried out by Vautard et al. (2019) questioned how climate change may have influenced the intensity and likeliness of the high temperatures experienced during the2019 heatwave.

The researchers collected data from weather stations across Europe to create two climate models, one which represented human-drive climate change, and another replicated the climate without huma intervention, prior to the industrial revolution.

The study concluded that the temperatures experienced during the July 2019 heatwave were ten times more likely due to the impact of climate change. Temperatures were approximately 1.5-3 degrees Celsius hotter than they would have been without human impact.

Sources:

https://www.metoffice.gov.uk/research/climate/understanding-climate/attributing-extreme-weather-to-climate-change



Credit NOAA

ARKEMA INC. CHEMICAL PLANT FIRE

On the 24th of August, 2017, a Category 4, hurricane made landfall in southeast Texas. Hurricane Harvey caused unprecedented rainfall across southeast Texas and southwest Louisiana, which led to devastating floods. This hurricane was the most significant tropical storm rainfall event in US history as well as the second most expensive hurricane after Hurricane Katrina.

Extreme flooding caused by Hurricane Harvey disabled the refrigeration system at Arkema Chemical Plant in Crosby, Texas which specialised in manufacturing organic peroxides. The flooding exceeded the equipment design elevations and caused the plant to lose power, back up power and critical organic peroxide refrigeration systems. The Arkema, Crosby plant is situated within a 100-year and 500-year flood plain.

It is vital that the peroxides are kept at a cool temperature otherwise combustion can occur. Due to this risk, everyone within a 1.5 mile radius of the plant were evacuated on the 30th of August 2017.

On the 31st of August 2017, a number of trailers on the plant spontaneously combusted, which was caused by an increase in temperature of the peroxides due to the failed refrigeration system. Twenty-one people had to seek medical attention following the fires due to exposure to fumes generated by the decomposing peroxides as the fumes travelled across a public highway adjacent to the plant.

A second fire occurred during the week following the flooding, as well as a controlled burn of existing trailers containing peroxides carried out by the Unified Command. Residents in the local area were unable to return home for a week.

Sources:

https://www.csb.gov/arkema-inc-chemical-plant-fire-/

Credit: KHOU.com

SOME LESSONS LEARNED:

The experiences from recent storms in the USA are being used to further improve resilience of chemical facilities. The following lessons learned were identified by the Louisiana Chemicals Association:

- Establish several ways to maintain critical communications with managers, suppliers, and customers both during and after the emergency; consider creating a mobile emergency operations centre.
- Focus on flood resistance and resilience as flood waters are usually the most serious obstacle to restarting operations.
- Prepare to quickly shut down key utility supplies like air, oxygen, nitrogen, steam, natural gas, and other raw material feeds.
- Establish plant evacuation routes, know the evacuation routes for your city or region, and communicate them to employees.
- Maintain internal contact lists so you can locate employees quickly.
- Maintain current contact information for emergency response groups.
- Investigate how to provide temporary housing, basic amenities, and medical services to employees, if necessary
- Carefully assess the makeup of 'ride out' teams that stay in place during a storm so that they include enough skilled craftsmen such as electricians, maintenance staff, and operators to get plants up and running again.
- Plants that are sole suppliers of specialty materials will come under pressure to safely begin producing as soon as possible. These companies in particular must have good communication links with their suppliers and contractors to ensure that everyone feels the same level of urgency. The best approach is to establish this in advance of the storm.
- Because secondary containment systems are designed to prevent releases of materials, they also prevented release of the corrosive sea water after the flood waters receded
- For facilities flooded by seawater, many pipes, vessels, and electrical systems have been damaged, and companies will be spending a long time and significant expense to repair or replace them. For the future, companies prone to storm flooding should design secondary containment systems with a dewatering capability
- The authorities only have limited resources available for infrastructure restoration and they must balance the needs of private industry and the public sector when establishing priorities, such as for restoring power. Therefore, the onus is also on chemical companies to make certain state and local authorities are aware of the interrelationships between individual plant sites and how plant closures can affect the economy and the ability of the country to meet the basic needs of its citizens.

TABLE A1: EXAMPLE IMPACTS TO OPERATIONS

Prompt question	Example impacts
O1	Lack of process water during drought causes disruption.
	Heavy rain or flooding means effluent system overloads with dilution water or other problems such as wash out of biomass. Effluent treatment plants are often gravity fed and therefore at the lowest, most vulnerable part of the site.
	High temperatures lead to poor cooling meaning that throughputs need to be limited or processes shut down if their cooling systems can't cope.
	Temperature impacts on catalytic processes leading to reduced performance e.g. effluent treatment where poor nitrification, reduced oxygen levels and increased odour present environmental issues.
	Maximum process relief rates are reduced due to high inlet temperatures and high flashing ratios.
	Extreme temperatures affect the operation of effluent treatment plant.
	Low temperatures lead to freezing of coolant lines to a chemical reaction vessel resulting in rising reaction temperature and pressure.
	Flooding compromises emergency relief systems that are designed for an atmospheric discharge pressure (not against a static head of water).
	Lack of water for fire-fighting, caused by either drought and poor availability of water, or prolonged severe cold temperature and freezing of lines.
	Abstraction licence could be revoked from 2028 onwards.
O2	High winds restrict crane lifts and working at height.
	Outdoor operations may need to be restricted during severe weather.
	Flooding prevents access so that facility cannot operate properly.
O3	Reduced river flow means the quality of incoming water deteriorates, reduced dilution of effluent and greater pollution.
	Process contamination by flood waters leading to large quantities of liquid effluent that require treatment e.g. from oil/water separators, sumps, drains, ground stocks of products or maintenance materials.
	Change in expectations in relation to how to comply with regulation where compliance is affected by weather leading to increased costs.
	Chemical release or venting during emergency shutdown causes breach in permit conditions.
	A switch to back up fuel due to weather related disruption leads to operating outside permit conditions on a temporary basis.
O4	Flood causes stored materials to react with water or be contaminated.
	Flooding causes floatation of empty/part full stock tanks, product or waste containers with subsequent loss of containment.
	Evaporation rates of volatile material increase with higher temperature, placing increased demand on cooling systems.
	High costs of storing water on site for managed disposal following heavy rain, especially if containment systems overloaded.
	Lightning strike causes process disruption that could lead to loss of containment.
O5	Flooding prevents access by staff, customers or vehicles, compromising business continuity and the ability to keep the site in a safe condition.
	Due to flooding or snow, land banks are not available for sludge spreading. Stock piles of sludge may lead to odour issues.
	Inclement weather restricts the movement of key staff around the site.
	Severe weather including snow and ice prevent key staff travelling to/from work.

A2: EXAMPLES OF IMPACTS TO LOGISTICS

Prompt question	Example impacts
L1	Disrupted in-coming and outbound deliveries due to blocked roads or difficulties at ports.
	Emergency services unable to access the site or are not available because of all the demands that are being placed upon them.
	Key staff not able to get to work.
	Increased road accidents due to bad weather.
L2	Weather or climate impacts on supplier affect the price, availability or quality of materials. Business interruption can result, particularly if there is only a single source of a key material.
	Increased risk provides an opportunity to strengthen supplier relationships and increase oversight of the supply chain.
L3	Severe weather causes loss of utilities (e.g. power, communications, steam, compressed gasses).
	Costs/ operational difficulties caused by underground pipelines being damaged due to expansion.
	Disposal of hazardous waste difficult due to impacts on sewage works or other waste services. Associated legislative issues of holding waste on site.
	Electrical storm causes power surge taking out power supplies, control systems and communications systems.
L4	The temperature range of volatile chemicals is exceeded during transport.
	More refrigerated distribution is required, increasing costs.
	Loss or hazard due to loss of containment during transport, such as of materials that are reactive or require refrigeration.

A3: EXAMPLES OF IMPACTS TO ASSETS

Prompt question	Example impacts
A1	Severe weather or flooding damages buildings fabric leading to disruption, repair and maintenance costs.
	Flooding or drought causes erosion of foundations and pipe supports.
	Snow and ice loading on tank roofs leads to loss of containment.
	Following heavy rain, water collects on tank roofs causing collapse and loss of containment.
A2	Extreme weather or flooding causes mechanical damage to process equipment, particularly equipment running hot subject to sudden thermal stress when inundated with water.
	Flooding causes equipment or machinery to be made unserviceable. For example, electrical equipment, switchgear, cabling, rotating mechanical equipment, control equipment and effluent treatment plants (because the biomass has been washed out).
	Bunds cracked by 'heave' from freezing ground.
	Water and other 'wet' lines freeze, leading to flanges, valve bonnets and other joints failing. This can lead to loss of boiler feed water lines, frozen cooling towers and frozen sprinkler systems.
	Repaired burst joints refreezing before effective lagging could be applied.
	Pneumatic control systems failing because instrument air is not dry enough.
	Lightning causes fire due to direct action or provision of an ignition source.
	Heavy rain overloads inlet air filters and causes damage to downstream equipment.
	Heavy rain causes water to collect on stock tanks roofs. For floating roof tanks this could possibly cause the roof to sink allowing a loss of containment of the tanks contents.
	High winds cause structural damage to process plant.
	High winds cause problems with floating roof tanks, partially lifting the roof and causing it to stick or at worst sink.
	Freezing weather leads to burst pipes or failures of primary containment including potentially simultaneous failure of multiple layers of protection.
	Loss of containment due to direct lightning strikes.

	Pipeline damage by cold weather, hot weather or subsidence.
	Electrical storm causes build up of static in insulated objects.
A3	High winds blow site litter or contaminated debris off-site.
	Flooding, heavy rain or drought causes landslide, subsidence.

A4: EXAMPLES OF IMPACTS TO PEOPLE

Prompt question	Example impacts
P1	High indoor temperatures lead to thermal discomfort and related building services issues.
	People's performance drops due to conditions of thermal discomfort, especially those in PPE.
	More complaints from staff.
	Inclement weather makes working outdoors unpleasant.
P2	Working in high temperatures can lead to heat stress and time off.
	High winds cause safety issues on site (too dangerous to work at height)
	Drivers are more at risk during bad weather.
	Unmanaged health risks could lead to industrial action.
	Lightning strike to a person causes injury or death.
	Lightning strike contributes to a fire.
P3	Staff absence due to school closures.
	Impacts on staff well-being and disruption to work attendance due to flooding or damage to own properties.

A5: EXAMPLES OF IMPACTS TO MARKET OR FINANCE

Prompt question	Example impacts
M1	Increasing/ decreasing demand for some products, such as de-icers, protective equipment, sun-cream ingredients, chemicals used in air conditioning or refrigeration.
	If more storage of hazardous substances is required there may be an impact on the site's COMAH status.
	New market for existing product.
	Potential to develop new product.
M2	Market advantage can be gained by being more resilient to severe weather and climate change.
M3	Climate risks affect price or availability of buildings or business continuity insurance.
	Resilience or adaptation measures reduce premiums or increase availability.
M4	Investors' perception of climate risks affect the price or availability of capital investment.
	Resilience or adaptation measures attract investors.

EXAMPLES OF RESILIENCE AND ADAPTATION MEASURES

Note: these are intended as illustrative examples only. The list is in no way designed to be exhaustive and there may be other options that should be considered. Equally, some of the measures below will not be appropriate to all businesses dependent on the complexity, processes, and range of hazards and vulnerabilities.

Examples of potential generic resilience measures

Capacity building

- Research to identify where on site or which sites are a priority for protection.
- Update list of contacts for before, during, and after an emergency including utility contact information for power outages.
- Improved interaction with Environment Agency.
- Interaction with Government or trade bodies to influence national strategy.
- Awareness raising with staff e.g. promoting dynamic risk assessments.
- Promoting an attitude that puts health, safety and wellbeing first and then prioritises business continuity above getting to work and being at work.
- Adequate on site communications.
- Train all shift personnel so that there are sufficient personnel available to operate the essential safety systems at all times or establish a plan and identify the resources required to get the extra personnel needed on site.

Operational

- Arrangements to ramp up/down production at short notice.
- Review the established procedures for safe shutdown, recovery, and restart of utilities and process operations.
- Ensure there is an evacuation plan, including support for employees.
- Increase stocks of fuel or consider alternative fuels.
- Alternative sources of key ingredients/ raw materials.
- Increase stockpiling.
- Arrangements for getting people to work or providing accommodation at times of disruption, and identification of where homeworking may be possible for some staff.
- Stop operations that require external intervention if a disruption compromises the ability of emergency services to access the site.
- Back up of electronic records.
- Offsite storage of products or third party manufacture.
- Ensure production trips to a safe condition in the event of loss of electricity.
- Real time liaison with the Local Authorities Silver Command to ensure that the requirements of 'Basis of Safety' can still be met during an incident.
- Ensure all safety critical systems have the appropriate safety intergrity, to reduce where necessary the risks from human factors failures.
- Ensure inspection and maintenance regimes are comprehensive and at an appropriately high level.
- Restrict access where there is a risk to health and safety
- Explore alternatives to roads for supply network.
- Ensure existing firefighting provisions on site are adequate to deal with a delayed and/or reduced response from the Fire and Rescue Service.

Physical/technical

- Have emergency onsite backup power – e.g. a generator, battery storage, or combined heat and power (CHP) system with adequate fuel storage.
- Update emergency power and supply options.
- Establish emergency communication systems and backup.

The examples given in tables A6-A8 are categorised by a) weather type or impact of relevance and b) business area where the corresponding impact is felt. This will enable examples to be linked to priority risks that have been identified in step 2.

TABLE A6: CAPACITY BUILDING MEASURES AIMED AT SPECIFIC IMPACTS

Measure	Weather/impact type								Business area				
	Flooding	Drought	High temps	Low temps	Wind storm	Electrical storm	Humidity	Wild ires	Operations	Logistics	Assets	People	Markets/ finance
Warnings and awareness raising for staff on the increased risks during hot and dry or inclement weather	X	X	X	X	X	X		X				X	
Look at international analogues	X	X	X	X	X	X	X		X	X	X	X	
Further research to assess risk using external experts	X	X	X	X	X	X	X	X	X	X	X	X	
Assess site vulnerability to wild fires and smoke from forests or moorland								X					
Use design limits to explore whether measures for heating, cooling, insulating or drying are required.			X	X			X		X	X	X	X	
Review pipework to identify which parts of plant or equipment may be vulnerable to heat or cold			X	X					X		X		
Provide specific information/ guidance on working in extreme temperatures or windy weather			X	X	X							X	
Use specialist techniques such as HAZOP or SIL to identify safety critical plant that may be susceptible			X	X					X		X	X	
Identify temperature thresholds where the risks associated with plant failure outweigh those of shutting down			X	X					X	X	X	X	
Talk to regulatory officer to discuss options if there could be the need to operate outside permit conditions	X	X	X	X	X	X	X		X				
Stress test control systems to rapid cooling of surfaces and modify if necessary	X								X		X		
Civil engineering checks of foundations	X	X			X						X		
Check capacity of existing systems for heating, cooling, drying			X	X			X						
Train staff in minimising the risk of lightning strikes to their person						X						X	
Factor lightning strikes of combustible materials or initiator of wildfires into risk assessments						X		X			X	X	

TABLE A7: OPERATIONAL MEASURES AIMED AT SPECIFIC IMPACTS

Measure	Weather/impact type							Business area				
	Flooding	Drought	High temps	Low temps	Wind storm	Electrical storm	Humidity	Operations	Logistics	Assets	People	Markets/ finance
Regime for regularly unblocking drains and drainage routes.	X											
Remove loose objects from site.	X				X							
Securing IBCs, drums and other containers.	X				X							
Raising IBCs, drums and other containers.	X											
Locate records, materials and inventory away from potential flood waters.	X							X				
Working for shorter periods with more breaks and providing drinks during hot weather.			X								X	
Improve storage of paper litter.					X							
Extra site gritting and snow clearance during cold weather				X				X		X	X	
An evacuation meeting point that is above potential flood levels	X							X			X	
At times of high risk amend shipping plans to ensure high stocks of raw materials and low stocks of product	X				X				X			
Shut down any vulnerable equipment in advance of a flood allowing enough time for cool down	X							X		X		
Shut down process and pumping operations to minimise process contamination in advance of a flood	X							X		X		
Shut down and isolate both the inlet and the outlet of the effluent treatment plant during the flood	X							X				
Following a flood, take care not to suddenly re-establish effluent flows on restart	X							X				
Ensure all vehicle movements are on hard standing	X	X						X		X	X	
Maintenance regime for air conditioning system			X					X			X	

Phase production to avoid hotter or drier periods			X	X				X	X		X	
Minimise stocks of products that deteriorate over time during hot weather			X						X			
Fire security measures: improved housekeeping, removal or cutting of vegetation			X			X		X		X	X	
Report and clear any very large icicles				X							X	
clear the snow from and grit roads and walkways				X				X			X	
Pipe in emergency sources of heat into the effluent system, e.g. boiler blowdown, hot condensate or even warm cooling waste return				X				X				
Minimise cold water flows and maximise strength of effluent (for biological treatment)												
Minimise cooling demand at times of water shortage by switching out marginal cooling requirements		X						X				
Alternative sources of cooling (other than with water)		X						X				
Tighten up control of recirculation and purge systems		X						X				

TABLE A8: PHYSICAL/TECHNICAL RESILIENCE MEASURES AIMED AT SPECIFIC IMPACTS

	Weather/impact type							Business area				
Measure	Flooding	Drought	High temps	Low temps	Wind storm	Electrical storm	Humidity	Operations	Logistics	Assets	People	Markets/ finance
Use flood-resistant building materials.	X							X		X		
Erect/ fit flood barriers or have temporary measures available.	X							X		X		
Build storm drains.	X							X		X	X	
Reinforce roof and siding panels.					X	X				X		
Install water storage systems such as rainwater harvesting		X						X	X			
Install odour control systems.			X					X			X	
Fit insulation to pipes or building			X	X				X		X	X	
Install blinds or shading			X					X	X	X	X	
Improve/ install ventilation			X					X	X	X	X	
Install/ improve systems for cooling			X					X	X	X	X	
Use building materials with high thermal mass			X					X		X	X	
Provide staff with more/ better PPE e.g. air-flow suits/ helmets for hot weather, insect repellent	X		X	X	X	X	X				X	
Fit trace heating for pipes.				X				X		X		
Cover windows and doors to prevent storm damage.					X					X		
Securing IBCs, drums and other containers.	X				X			X		X	X	
Anchoring tanks and other structures								X		X	X	
Scaffolding and sheeting of pipetracks and some process plants as a precaution in advance of severe cold				X				X		X	X	
Provision of warm clothing and PPE during cold weather				X							X	
Site cabling and electrical equipment above likely flood levels	X							X		X		
Specify power systems for operation in submerged conditions	X							X		X		

Segregation of effluents on site with closed pumping and storage systems during a flood	X							X				
Relocate discharge points above maximum predicted flood levels	X							X		X		
Improve site drainage and roof drainage	X							X		X		
Civil engineering measures to combat landslide, subsidence, heave or wind damage	X	X		X	X					X		
Improve site/ building design to combat landslide, subsidence, heave or wind damage	X	X		X	X					X		
Choice of building materials for higher level of protection	X	X	X	X	X	X	X			X	X	
Tertiary containment with overflows directing potentially contaminated waters to where they will cause the least harm to people or the environment	X							X			X	
Extra hardening of surrounds of foundations of susceptible structures	X	X		X	X					X		
Change blends in summertime to reduce volatility			X					X				
Ensure process relief devices are adequately sized			X					X				
Improved filtration and anti-algal growth systems			X					X				
Strengthen buildings and process plant					X					X	X	
Provide buildings and other structures with suitable protection against lightning						X				X	X	
Stock tank vents from flammable stock tanks may be provided with flame arrestors						X				X	X	
Amend process to reduce cooling demand		X						X				
Recirculate treated effluent at times of low water availability		X						X				
Reduce water demand of effluent plant by minimising sources of contaminants		X						X				

Introduce recirculation of scrubbing water on once through systems												
Import water		X						X				
Design Effluent Treatment system such that the final effluent will not cause harm to the receiving environment even if released undiluted		X						X				

TABLE A9: IDENTIFYING POTENTIAL IMPACTS (IN SUPPORT OF STEP 2 OF THE GUIDE)

Business area	Responsibility	Weather-related hazard that could affect business area or cause environmental harm	Describe past or potential effects on business area or environment	Adaptation action already taken
Operations				
Logistics				
Assets				
People				
Markets				
Finance				

TABLE A10: RISK ASSESSMENT (IN SUPPORT OF STEP 2 OF THE GUIDE)

Potential impact	Critical threshold (if relevant)	Likelihood *	Magnitude *	Priority

TABLE A11: MONITORING WEATHER EVENT LOG (IN SUPPORT OF STEP 4 OF THE GUIDE)

Business area:			
Date	**Weather event**	**Extent of incident**	**Damage/effect to the business or environment**

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