Credit risk impacts of a changing climate

The topic of climate change commands significant profile in the media and increasingly in business circles. Much of the associated debate focuses on greenhouse gas emissions and the business impacts of a carbon constrained economic arena, whereas the potential consequences to businesses of a changing climate have, to date, not attracted the same level of attention.

This imbalance needs to be redressed. Regardless of the success and rate at which greenhouse gas emissions are controlled, some climate change is locked into the world's weather system over coming decades and these changes may represent material risks (or opportunities) to business. By implication these impacts may be valid considerations in the credit risk analyses undertaken by lending banks.

Changing weather patterns may impact business in a variety of ways, including the physical risk to fixed assets arising from storm damage or flood, impacts on the supply chain arising from increasing scarcity of natural resources such as water, and shifting patterns in demand for goods and services due to increased extremes of temperature. They may impact asset values, and hence potentially weaken a company's balance sheet; they may increase costs, as raw materials or other inputs become scarce, or as operations or working practices need to change; or they may reduce or stimulate the demand for a company's products or services.

The accompanying briefing paper has been developed as a collaboration between Barclays Environmental Risk Management and climate risk management specialists, Acclimatise. The sectors considered have been chosen to demonstrate that climate change risks are potentially material for operations dependent upon substantial fixed assets and infrastructure, including the Energy sector, but also in sectors as diverse as Chemicals and Pharmaceuticals and Tourism. The briefing paper is drafted in non-technical language to help bank business and credit teams appreciate the nature of these potential risks.

Given the diversity of potential impacts, which will vary in significance across different geographies and time horizons, between different industry sectors and individual companies, it is not possible to develop a prescriptive approach and so this paper deliberately raises more questions than answers.

The extent to which these potential impacts may be material in the context of any given transaction will be for the business manager or the credit officer to determine. If there are possible concerns, the paper provides some examples of potential risk management actions which may provide some comfort, and also sources of reference if further enquiry needs to be made. Clearly, technical expertise is available through specialist consultancies such as Acclimatise where more rigorous or detailed analysis is required.

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Contents

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Section 1

Overview

Overview

The climate is changing, due to emissions of greenhouse gases from human activities, which enhance the natural greenhouse effect. Since the industrial revolution, human activities have increased atmospheric concentrations of the most important man-made greenhouse gas, carbon dioxide (CO_2), by one-third. By the end of the 21st century, they are expected to be two or three times higher.

Even if we are able to make dramatic reductions in greenhouse gas emissions immediately (mitigation), we would still have to acclimatise (adapt) to rising temperatures, changing rainfall patterns and centuries of sea level rise, because of inertia in the global climate system.

This briefing paper provides an overview of the key risks and opportunities posed by a changing climate for businesses in a number of sectors. The impacts of a changing climate will affect companies in different sectors and geographies in different ways and to a varying extent. Some businesses will benefit from climate change; some will undoubtedly be very adversely affected. These risks and opportunities need to be identified and understood. Once they have been assessed, the risks and opportunities can be proactively managed, by 'acclimatising' business strategies and activities.

This section in this briefing paper provides some generic strategies for climate risk management, followed by a description of particularly vulnerable locations. The rest of this document examines specific climate risks and opportunities for the following types of businesses:

- Those with long-lived, fixed assets in all sectors,
- Chemicals and pharmaceuticals,
- Fossil fuel and nuclear power generation, supply and distribution,
- Renewable power generation, supply and distribution, and
- Tourism.

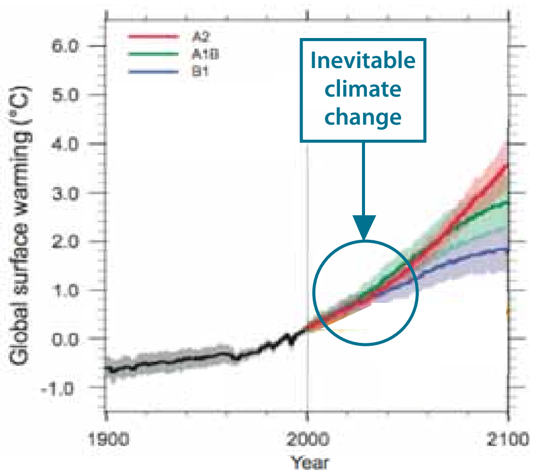

Figure 1: *Annual average global temperature increases to 2100 under different greenhouse gas emissions scenarios relative to the 1980-1999 baseline. The B1 scenario represents a future where clean and efficient technologies are used. The A2 and A1B scenarios describe future worlds where economic growth is rapid and the environment has lower priority. [Source: IPCC, 2007].*

Generic climate risk management actions

These generic measures can be used by businesses to acclimatise their strategies and activities to inevitable climate change. Many of them can also be used by banks lending to, or investing in those businesses.

Address climate risks in corporate risk management systems, to ensure that they are identified, assessed and managed appropriately as part of mainstream business planning.

Identify the opportunities that climate change presents before competitors do – such as changes in markets for products and services due to climate change – to gain an 'early mover' advantage.

Understand and monitor the climate change positions of external stakeholders (including government, regulators, insurers, investors, lenders, competitors and suppliers) to proactively engage with them on climate change adaptation. Stakeholder positions on adaptation are evolving rapidly, for instance regulations in some countries are already being amended for climate change adaptation.

'Climate-proof' new projects at the design stage through siting of new facilities to take account of climate change and by incorporating other adaptation measures that are robust in the face of climate change uncertainties. These measures can include:

- 'No-regret' measures – that deliver benefits that exceed their costs, whatever the extent of climate change.
- 'Low-regret' measures – are low cost, and have potentially large benefits under climate change. Taking account of climate change at the design stage for a new project will often yield low-regret measures.

Review existing sources of raw materials, assets, operations and processes for vulnerability to changing climate risks. Building, engineering, manufacturing, operations and production process designs may be flawed if they were developed based on historic climate data. Identify those most at risk and make priorities for adaptation by:

- Identifying climatic sensitivities and critical thresholds that represent the boundary between tolerable and intolerable levels of risk,
- For climate variables with higher confidence, make an allowance for long term climatic trends – e.g. for temperature increases over the lifetimes of facilities.

Review design standards and codes of practice to identify those that include climatic factors. While national or international standards may not yet reflect climate change, they will be updated over time. Companies should upgrade their design standards and codes of practice where required to take account of predicted climate changes. Historic climate data, on which many standards and codes are based, are no longer a good guide to the future.

Review existing measures that aim to manage current climate or weather risks to see whether they provide sufficient protection against changing climate risks. In some cases, additional allowances will need to be made to build in 'headroom' for climate change. Keep options open through adaptive management by putting in place incremental adaptation options over a project's lifetime, rather than undertaking large-scale adaptation in one step. Avoid actions that will make it more difficult to cope with future climate risks.

Use financial risk management mechanisms, such as insurance, weather derivatives and forward trading in commodities to manage climate risks.

Address climate risks and risk management measures as part of Environmental and Social Impact Assessments (ESIAs). If an ESIA does not take account of climate change, the development may not perform as intended over its lifetime. In particular, the risk management measures proposed in the ESIA may not deliver their intended benefits, and damage to the environment could occur as a result. Review existing ESIAs that have not taken account of changing climate risks.

Take steps to **build internal capacity on adaptation** by raising awareness, developing a corporate understanding of climate risks, assigning responsibility for adaptation to staff and adopting a consistent approach.

Vulnerable locations

Some geographical locations are more vulnerable than others to particular climate hazards. It is at these locations that the imperative for adaptation is greatest.

	Changing climate hazard	Particularly vulnerable locations
	Average temperature rise and increased risk of heat waves.	• Regions where average temperatures are already high, • Regions where temperature thresholds may be crossed (e.g. permafrost zones, mountainous regions), • Urban centres, where the Urban Heat Island effect (the localised pool of warm air that frequently builds up over towns and cities) will exacerbate high temperatures.
	Mean sea level rise, increased storms surge heights, wave heights, coastal flooding and erosion.	• Coastal zones and islands, • Offshore locations.
	Decreased seasonal precipitation, increased risks of drought, subsidence and wildfire.	• Regions where rainfall is already scarce, • Locations where current demand for water almost matches or outstrips supply, • Locations where water quality is poor, • Water resources dependent on glaciers (those areas dependent on glacier melt are probably observing increases in water resources in the short term, as glaciers melt faster, but over time, the loss of glaciers will lead to decreases in water resource availability), • Subsidence-prone soils, • Regions prone to wildfire.

Vulnerable locations

Changing climate hazard		Particularly vulnerable locations
	Increased seasonal precipitation and more rapid snow melt, leading to increased risk of river flooding. Increases in heavy precipitation events leading to increased risk of flash floods and soil erosion.	• Regions with high rainfall, • Estuaries, deltas and river floodplains, • Mountainous and glacial regions, • Locations prone to landslip, • Urban centres with stormwater systems that are not designed to manage short duration intense rainstorms, • Contaminated environments (land, water).
	Possible increased storm intensity and frequency.	• Areas at risk from tropical storms (including hurricanes, typhoons, cyclones) and extra-tropical storm events particularly in urban areas.

Analysing risks, opportunities and risk management options

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The following tables outline the key climate risks, opportunities and adaptation strategies for a variety of sectors.

On the left-hand side of each table, risks and opportunities arising from a changing climate are grouped into the following four categories:

Raw materials, supply chains and logistics

Many sectors, particularly those with large fixed assets, are heavily reliant on energy, water, and raw materials. Climate-related impacts on the supply of these resources will affect sector performance. Climate variability and climate change can also trigger interruptions to supply chains and distribution systems, with subsequent cost implications.

Assets, site conditions and workforce

Employees in all sectors are vulnerable to extreme climatic events. Assets are designed to perform a specific function, and to the extent that these reflect climate conditions these are normally based on historic climate data. As the climate changes, these assets may no longer be fit for purpose, leaving their performance and value at risk. As facilities age, and as more demand is put on them, they are more likely to fail under extreme events and incremental climate change. Site conditions are also profoundly affected by a changing climate, leading to increased flood risk, changing groundwater levels, increased risks of subsidence, heave, landslip and soil erosion, as well as thawing permafrost in some locations.

Operations, processes, products and markets

Many sectors rely on complex operations and production networks which are vulnerable to interruption, with knock-on impacts on quality, timeliness, precision and performance. Companies with global markets or suppliers will be affected by climate change impacts in other countries. People tend to consume different kinds of products in different weather conditions and in different seasons. Market opportunities will result from climate change.

Local communities and natural environments

Asset owners and operators have a responsibility to avoid negative impacts on local communities and environments. As climate change will put additional pressure on already scarce resources, new climate risks over the life of a project should be taken into account as part of Environmental and Social Impact Assessments.

Sector specific risk management options

The right-hand side of each table shows how companies in each sector can acclimatise to reduce their exposure to changing climate risks. The cost and complexity of implementing each risk management option for new assets (at the design stage) and existing assets (through retrofit) is indicated using the following symbols:

These categories represent a subjective judgement of the cost and effort required to implement each solution. In general, adaptation of existing assets and projects will be more difficult to achieve (through retrofit, rebuild etc) than adaptation of new assets and projects at the design stage. The categories also take account of the complexity (e.g. large engineering project vs. local policy change) and the degree of inter-agency cooperation required to put each risk management option into operation. Local conditions and circumstances will influence the complexity of implementing adaptation solutions. For example, the same risk management option may be relatively more difficult to employ in particularly vulnerable locations (described above). In recognition of these variables, a range of severity symbols are sometimes presented for a single risk management measure.

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Section 2

Climate risk management for **long-lived, fixed assets** in all sectors

2.1 Raw materials, supply chains and logistics

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Risks and opportunities	Risk management options	Significance Design stage	Significance Retrofit
Low river flows during hot, dry summers can lead to restrictions on water abstractions, with consequences for cooling and industrial processes when the need for cooling is highest. During times of drought, demand for water resources from third parties will also increase, leading to increased competition for a scarce resource. Low flows can worsen water quality, which is an important consideration for industrial process waters. When extreme temperatures cause spikes in energy demand, power generation systems are likely to be stressed and less able to meet higher demand. During the summer of 2004 there was a significant rise in the use of air conditioning in France. This coincided with the months when output from nuclear power (the dominant power source) stations was constrained by lack of cooling water, threatening blackouts. Facilities dependent on energy from hydropower plants may also experience reduced power availability during times of drought.	• A range of water resource management measures including: developing alternative water supplies, reservoirs, water efficient processes, rainwater harvesting and storage, water recycling, etc.		
	• Water balance modelling for new facilities should take account of climate change projections.		
	• Increased investment in water treatment to achieve required water quality standards		
	• Energy demand management measures that influence the quantity or patterns of use of energy consumed by end users can be implemented to reduce peak demand during periods when energy-supply systems are constrained.		
	• Install back-up power generators.		
During hot weather, when demand for power peaks, power output from combustion turbine power plants decreases significantly (up to 35% below rated capacity) and fuel consumption for power generation increases, with implications for higher greenhouse gas emissions per kWh and higher costs.	• Construction of new power plant to deal with increased demand		
	• A range of technologies for cooling the input air as it enters the turbine, for instance: • Evaporative coolers - devices which use evaporation of water to cool the air, • Adding water vapour, • Chillers.		

2.1 Raw materials, supply chains and logistics

Risks and opportunities	Risk management options	Significance Design stage	Significance Retrofit
Supply chains and transport links are vulnerable to climate related disruptions, including flood events, heat waves and/or landslip caused by heavy rainfall. For instance, heat waves can cause buckling of railway lines and melting of tarmac road surfaces. Higher temperatures can also melt ice roads and thaw permafrost, affecting transport infrastructure. Companies that are dependent on government-owned transport infrastructure over which the private companies have no control are particularly vulnerable to climatic risks, if the infrastructure is not designed appropriately to take account of climate change risks.	• Provide additional storage capacity to carry higher inventories of products and raw materials and maintain supplies in the event of disruption.		
	• Engage with government and transport providers to ensure that transport infrastructure is resilient under a changing climate.		
	• Consider investment in private transport links for particularly vulnerable routes or locations.		
Disruptions and delays to 'just-in-time' distribution systems can lead to plant closures.	• Companies should conduct an enterprise vulnerability assessment – an analysis of which types of supply chain disruptions would be most likely to affect their particular business, e.g. raw materials and parts, transport, communications, etc.		
	• Businesses should cultivate good supplier relationships and consider using multiple suppliers in case of disruption in supply.		
	• Providing additional storage facilities on-site – for instance for vital raw materials – can help to minimise the effects of disruption.		

2.2 Assets, site conditions and workforce

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Risks and opportunities	Risk management options	Significance Design stage	Retrofit
The comfort and productivity of outdoor, production line and factory workers can be compromised by warmer working conditions. Dangerous conditions can arise during heat waves. Maximum workplace temperatures may be imposed, which could result in significant capital and revenue costs. The safety and performance thresholds for buildings, infrastructure and plant may not be climate-proof, if designed based on historic climate data. This may lead to additional and unplanned capital and revenue expenditure during asset life. The need to cool buildings, processes and workplaces may lead to increased use of energy and increased greenhouse gas emissions. Energy Efficiency Certificates may be compromised.	• Adjust workers' shift patterns and clothing/equipment.		
	• Provide shade.		
	• A number of structural solutions offer effective means of managing heat risk and reducing thermal discomfort, including: • Planting, shading and advanced glazing systems to reduce solar heat gain, • Use of cool building materials, including green roofs and walls, to reduce heat penetration, • Innovative use of water for cooling, including groundwater cooling using aquifers or surface water, • Mechanical cooling, including chilled beams (beams with water running through them) and conventional air conditioning systems, • Increasing ventilation and removing heat using fresh air (only effective when outside air is cool), • Use of heavyweight building materials that absorb heat during hot periods so that it can dissipate in cooler periods, usually using ventilation.		

2.2 Assets, site conditions and workforce

Risks and opportunities	Risk management options	Significance: Design stage	Significance: Retrofit
Climate change will introduce new pests and diseases into previously unaffected areas and could create new health risks for workers. In September 2007 there were reports that a tropical virus, which is carried by mosquitoes and affects humans, had become established in Europe for the first time. The Italian Ministry of Health confirmed about 160 cases of chikungunya in the Ravenna region of northern Italy. The virus causes high fevers and joint pain, as well as headache, muscle pain, rash and less frequently, gastrointestinal symptoms. One death was reported in an 83-year old with underlying medical conditions. There is no vaccine against chikungunya.	• Health and safety procedures should be stress-tested for their ability to cope with new disease outbreaks		
	• Establish links with national and international health agencies monitoring changing disease patterns.		
	• Work with local governments and communities to assess vulnerability.		
Sea level rise, increased precipitation and river flows can increase flood and coastal erosion risks. This can lead to asset damage, inability to operate and downtime during clean up operations. Areas at risk from flooding may become uninsurable. Existing flood management systems will be compromised by sea level rise, storm surges, increased seasonal precipitation, and increased risk of river and flash floods. This may lead to increased premiums, wider exclusion clauses and removal of cover. Loss of cover will have an impact on asset value and availability of finance. Increased exposure to flood risk for workforces and communities in the vicinity of industrial sites.	• Siting and design of new facilities taking account of climate change. Relocation of existing facilities may be necessary in some cases.		
	• Flood and coastal erosion management strategies for existing facilities include: • Diversion of flood flows away from areas at risk, • Upstream flood attenuation and temporary water storage, • 'Set-back' flood defences and/or permanent hard barriers, • Increasing drainage capacity, • Sustainable Drainage Systems (SuDS), which allow water to soak gradually into the ground, • Flood resilient building materials, • Raising floor levels, • One-way drainage valves, • Removable temporary flood barriers.		

2.2 Assets, site conditions and workforce

Risks and opportunities	Risk management options	Significance Design stage	Significance Retrofit
Increased risks of subsidence, heave, landslip and erosion can adversely affect foundations, pipelines and transport infrastructure.	• Siting and design of new facilities taking account of climate change. • Existing facilities may require repair, maintenance and upgrading to take account of changing conditions. In extreme cases, existing facilities may need to be relocated.		
Changes in groundwater levels (due to increased recharge or saline intrusion) can create new pathways, potentially leading to new contaminated land issues and regulatory consenting failures. Insurance cover and bonds may be compromised.	• Contaminated land assessments and monitoring should explore the future impacts of climate change on contamination pathways.		

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Risks and opportunities	Risk management options	Significance Design stage	Retrofit

Large fixed assets may be vulnerable to extremes of wind and driving rain. Climate change may lead to more extreme weather patterns causing increased damage costs.
Areas at risk from major storms may become uninsurable.
There is some evidence that climate change will lead to an increase in cyclone activity and intensity and also monsoon intensity which could pose a threat to businesses, particularly on the coast.
	• Siting and design of new facilities taking account of climate change.
	• Apply strict building codes for storm resilience.
	• There are many alternative building forms or strategies that minimise wind loads on new buildings including:
	  • Aligning the strong axis of the building into the prevailing wind direction,
	  • Minimising the height of vertical walls,
	  • Avoiding large openings on windward walls,
	  • Using hip or mansard roofs,
	  • Minimising roof overhangs,
	  • Introducing porosity into cladding and roofing systems,
	  • Arranging buildings in a way that maximises shelter and avoids large variations in the height of adjacent buildings.		

	• Identify cost-effective measures for adapting existing buildings and other assets to future wind extremes, including:
	  • Improving maintenance regimes,
	  • Making gutters, eaves, verges or ridges more aerodynamic,
	  • Introducing roof vents to reduce wind uplift,
	  • Using roof netting systems to hold tiles and slates in place.		

2.2 Assets, site conditions and workforce

Risks and opportunities	Risk management options	Significance Design stage	Significance Retrofit
Emergency response procedures can be compromised by poor ground conditions and flooding. Significant increases in material, labour and reconstruction costs can occur following an extreme event (often referred to as 'demand surge'). There can be difficulties in recruiting and retaining staff following a major event, e.g. Hurricane Katrina. Local workers whose homes, communities or transport links are affected by floods or storms will be unable to work.	• Emergency response procedures and business continuity plans should be tested to ensure they can cope with increased occurrence and intensity of extreme climatic events.		

2.3 Operations, processes, products and markets

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Risks and opportunities	Risk management options	Significance Design stage	Significance Retrofit
Low river flows due to reductions in seasonal rainfall can lead to restrictions on the volume of water that companies are allowed to abstract from rivers, with impacts on production.	• Siting of new plant should consider the potential impact of climate change on water resources, as well as the knock-on impacts for local environments and communities competing for those resources.		
	• A range of water resource management measures including: developing alternative water supplies, reservoirs, water efficient processes, rainwater harvesting and storage, water recycling, etc.		
	• New asset design should take full account of potential future water constraints, and existing plant should be retrofitted to deal with potential water shortage, for instance through grey water recycling and other water conservation practices.		
Air coolers may be unable to cope effectively during heat waves, leading to reduced production.	• New air coolers should be designed with sufficient capacity to cope with the temperature increases they will experience over their lifetimes. Existing facilities may need to install extra cooling capacity.		

2.3 Operations, processes, products and markets

Risks and opportunities	Risk management options	Significance Design stage	Significance Retrofit
Efficiencies of on-site power generation facilities are reduced in higher temperatures. Output from many forms of generation, particularly gas- or steam-fired, is lower in hot weather. Electricity supplies are at risk during sustained high temperatures as generators fail to meet increased peak demands and distribution systems fail under loading.	• Energy demand management strategies may help to reduce strain on power grids during hot summers.		
	• Climate risks, and particularly heat risks, should be considered in the planning of any future power stations, as well as during major upgrades of existing stations.		
	• The design of cooling systems should be reviewed in the light of climate change. Current gas turbine design and efficiency should also be reviewed and modified if necessary. Inlet cooling systems may be installed to cool inlet air as it enters gas turbines.		
	• Small, distributed power systems may be more resilient in the face of climate change.		
	• Technical modification to power generation plant may be possible to increase efficiencies during warmer average temperatures and higher extremes of hot weather.		
	• Additional power generation facilities may be built to meet extra demand.		
Efficiencies of compressors are reduced in higher temperatures.	• The design of compressors should be reviewed in the light of climate change. New facilities may require larger compressors. Existing compressor stations may require additional cooling and hence more fuel.		

2.3 Operations, processes, products and markets

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Risks and opportunities	Risk management options	Significance: Design stage	Significance: Retrofit
Data centres, which host and maintain back-end server computers in specialised premises, are vulnerable to flood risks, extremes of high temperature, and storms. These centres control flow and security of valuable data, and climate risks can contribute to serious disruptions.	• Data centre facilities should be designed or upgraded to ensure they are equipped to provide the power and cooling needed to prevent computers from crashing.		
	• Businesses should establish and rehearse record retention and disaster recovery plans.		
	• Data centre facilities should be sited away from vulnerable locations. Existing locations may be able to reduce flood risk by keeping non-critical equipment only on the ground floor.		
Disruption to business leading to loss of markets to competitors and financial impacts following a major weather event, e.g. Hurricane Katrina.	• Business continuity plans should be tested to ensure they can cope with increased occurrence and intensity of extreme climatic events.		
	• Plant should be designed or upgraded to be resilient in the face of future, rather than historical, climate. Designs should be tested for their ability to cope with potential future changes in storminess.		

2.3 Operations, processes, products and markets

Risks and opportunities	Risk management options	Significance Design stage	Retrofit
Over short time scales, impacts on operations and processes tend to be associated with extreme weather events (e.g. floods and heat waves). These events can lead to localised or system failures. Over the longer term incremental climatic changes will have a significant impact on a system's operating and safety thresholds, as well as the deterioration of raw materials and products. These are not as apparent as extreme failures and can easily be overlooked if not actively evaluated. Existing assets may require continuous repair and maintenance, with associated costs.	• The basis of design for operations and processes should be reviewed and revised where necessary to reflect projected climatic extremes rather than historical data. This might require changes (e.g. refrigeration) to storage facilities or and process operations.		
	• Inspection and maintenance regimes for storage and process facilities should be reviewed.		
	• The use of monitoring systems to detect or predict quality or safety problems should be explored.		
	• Safety thresholds and procedures should be reviewed in the light of projected changes in temperature.		

2.4 Local communities and natural environments

Risks and opportunities	Risk management options	Significance Design stage	Significance Retrofit
Excessive draw-down on groundwater resources can lead to changes in groundwater levels and saline intrusion. This can create new pathways, potentially leading to contamination of local environments (land, watercourses) by affected industrial operations. Regulatory consenting failures may occur as a result and insurance cover and bonds may be compromised. The risks of land contamination and air and water pollution increase following a major storm event, e.g. Hurricane Katrina.	• Siting and design of new facilities taking account of climate change. • For existing facilities where insufficient water resources exist to avoid contamination of local environments in future, opportunities to relocate should be sought.		
	• Contaminated land assessments and monitoring should explore the future impacts of climate change on contamination pathways.		
Water resource difficulties will intensify with climate change, with potential impacts on availability of water for surrounding communities and natural environments.	• Work with local communities to develop and implement measures to cope with drought risks.		

	• Ensure that sufficient water resources are available over a facility's lifetime, taking account of:
	  • Likely increases in demand for resources from local communities and natural environments,
	  • Regulatory risks that may arise during low flow conditions.
	• Where insufficient resources exist, a range of water resource management measures can be used including: developing alternative water supplies, reservoirs, water efficient processes, rainwater harvesting and storage, water recycling, etc. In extreme cases, opportunities to relocate may need to be sought.		

	• Water balance modelling should take account of climate change impacts on water resources (surface and ground water), and of the impacts of climate change on other water users.		

2.4 Local communities and natural environments

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Risks and opportunities	Risk management options	Significance Design stage	Significance Retrofit
Low river flows have less capacity to dilute effluent discharge, with adverse effects on water quality and consequent impacts on natural environments and local communities.	• Review the ability of water treatment plant to cope with lower water quality at times of low flow, taking account of climate change projections. Existing plant may need to be upgraded.		
Increased areas of hard standing combined with heavy rainfall can increase risk of flash flooding and rapid run-off, potentially affecting local communities and natural environments in the vicinity of a facility.	• Flood risk assessments should identify land at risk and the degree of risk, taking account of climate change.		
	• New industrial facilities and fixed assets should be directed away from flood risk areas if possible. Land that is required for current and future flood risk management should be safeguarded.		
	• Design and location of new assets should take account of a changing flood risk and its impacts on local communities and natural environments		
	• Risk assessments should be conducted for existing assets to assess sensitivity of design and location to changing flood risks.		
	• Site designs should aim to address changing flood risks by incorporating measures to manage site run-off, including: water storage, increased drainage capacity and waste water treatment capacity, Sustainable Drainage Systems (SuDS, which allow water to soak gradually into the ground), to ensure the site does not increase flood risks to local communities and natural environments.		

2.4 Local communities and natural environments

Risks and opportunities	Risk management options	Significance Design stage	 Retrofit
Changing climatic conditions will directly affect flora and fauna. Species will migrate to new locations in response to changes and may be lost from locations where they are currently found. Habitats will also be affected – for instance, coastal habitats could be lost as sea levels rise. In addition, climate change will cause migration of pests, diseases and invasive species, potentially affecting flora and fauna. This may lead to local loss of protected species in the vicinity of a facility. Activities at a facility could be held responsible for loss of species/habitats, whereas larger-scale factors associated with climate change are actually responsible.	• Investigate and monitor pests, diseases and migration of important species and habitats.		
	• Incorporate the potential impact of climate change on species and habitats in the ESIA process.		

Section 3

Climate risk management for the **chemicals** and **pharmaceuticals** sector

3.1 Raw materials, supply chains and logistics

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Risks and opportunities	Risk management options	Significance Design stage	Significance Retrofit
Many drugs require refrigerated storage as they are unstable at ambient temperatures over extended periods of time. With rising temperatures and increased risk of heat wave events, some drugs stored in doctors' surgeries, retail chains or at home may lose efficacy or begin to degrade.	• Safe storage guidelines and recommendations should be designed or revised to take account of climate change. Expiry dates may need to be shortened.		
	• New technology that allows the delivery of drugs, vaccines and other active pharmaceutical ingredients in solid form reduces the need for refrigerated storage during hot weather.		
Availability of raw materials, and processing / production of chemical and pharmaceutical feed-stocks can be affected by a range of climate risks, including flooding and potential increases in storminess.	• Additional storage capacity for products and raw materials may be beneficial in case of disruption to supply.		

3.2 Operations, processes, products and markets

Risks and opportunities	Risk management options	Significance Design stage	Retrofit
Higher temperatures and heat waves can compromise chemical and pharmaceutical processes and affect corrosion rates, physical properties of end products and storage times. This has knock-on impacts on performance conditions and quality standards for production processes. Safety thresholds may be compromised by higher temperatures leading to an increased risk of plant failure (explosion, fire, pollution, loss of life).	• Monitoring systems should be geared up to detect or predict quality or safety problems as a consequence of extreme temperatures.		
	• Install additional cooling capacity sufficient to take account of projected increases in extreme temperatures.		
	• Safety thresholds and procedures should be implemented or reviewed in the light of projected changes in temperature.		
	• Design standards should be calculated or revised to reflect projected climatic extremes rather than historical data. This might require changes to storage facilities and/or process operations.		
	• Inspection and maintenance regimes for storage and process facilities should be designed or reviewed to take account of a changing climate.		

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Risks and opportunities	Risk management options	Significance Design stage	Significance Retrofit
Significant opportunities and new markets exist within the pharmaceuticals industry to deliver products and treatments which meet the challenges of new diseases and health issues. Climate change may cause disease vectors to spread to new locations. Opportunities exist in the following areas: • UV exposure – levels of UV radiation reaching the earth's surface may increase due to sunnier summers, less cloud cover and ozone depletion (which reduces the capacity of the ozone layer to absorb UV). • Vector-borne diseases – various diseases transmitted by mosquitoes or ticks are climate-sensitive and can increase or be introduced to previously uninfected areas due to climate change. • Food poisoning – higher summer temperatures could cause increases in food poisoning episodes like salmonella infection. • Water-borne disease – climate change might increase levels of cryptosporidium and campylobacter in water (typically acute, short term infections that can become severe or even fatal for children and adults with weakened immune systems). • Bacterial contamination – Legionnaires disease, for example, may increase.	• Marketing and business development analysis should assess the impacts of climate change on customer needs.		

3.3 Local communities and natural environments

Risks and opportunities	Risk management options	Significance: Design stage	Significance: Retrofit
Extreme weather may affect chemical processes and storage facilities, increasing the potential for contamination of local environments. Chemicals and pharmaceuticals companies face regulatory risks if handling, transmission and storage safety standards are compromised during flood, heat wave, or storm events. Waste management practices and waste water treatment facilities may be compromised. Biosecurity breaches at a UK government laboratory in Pirbright, Surrey, led to an outbreak of Foot and Mouth Disease in July 2007. One of the factors leading to the outbreak was heavy rainfall and localised flooding, which caused high groundwater levels on site. Groundwater then entered the site's poorly maintained drainage system through cracks and misalignments in pipework. This allowed the virus, which was in the drainage system, to enter the groundwater and eventually spread off site.	• Companies should review industrial processing and storage procedures, taking account of climate change. Environmental and social impact assessments should take account of current and future climate risks.		
	• Engage with local government and communities on robustness of water resources in the face of climate change, to ensure industrial operations and storage facilities do not make local communities more vulnerable.		
	• Design of facilities or technical modification to plant to allow operation during warmer average temperatures, dry periods, and extreme events.		
	• Monitoring and maintenance regimes for drainage and waste water treatment facilities may need upgrading to take account of increased risks due to climate change.		

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Section 4

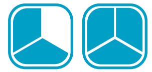
Climate risk management for **fossil fuel** (crude, coal and natural gas) and **nuclear power generation, supply** and **distribution**

4.1 Raw materials, supply chains and logistics

Risks and opportunities	Risk management options	Significance Design stage	Significance Retrofit
Many power stations are cooled by river water. A reduction in river flow can reduce efficiency and output or even require a plant to shut down if inadequate water is available for cooling purposes. Hotter temperatures and decreased stream flows also increase the risk that river water will be insufficient to dilute cooling water effluent. In these cases power stations may be forced to reduce output in order to meet regulatory pollution control standards. Significantly, these episodes usually coincide with peak demand for energy for cooling. During the hot summer in 2003, 17 nuclear reactors in France operated at reduced capacity or were forced to shut down. To make up supply, Électricité de France had to buy electricity on the open market at 10 times usual summer rates. In the spring of 2007 Southeast Queensland's 2.5 million residents faced power blackouts and water restrictions as the region's two main power stations were forced to cut production because of shortage of cooling water. During the July 2006 heatwave, Spain was forced to shut down the Santa Maria de Garona nuclear reactor, which generates 20% of Spain's national electricity, because the Ebro River water it uses for cooling had warmed dramatically and was no longer safe to use as a coolant. Similar problems affected inland nuclear reactors in Germany that use river water for cooling.	• Problems can be addressed to a limited extent by rescheduling traditional summertime maintenance to less energy-intensive seasons, or by seeking temporary permission to increase cooling water discharge temperatures.		
	• Siting of new plant should consider the potential impact of climate change on water resources. Relocation of industrial power plant may be necessary if future water resources are insufficient. Since salt water is usable for power plant cooling, coastal locations may be more suitable.		
	• In areas which are likely to be increasingly water-stressed a range of water resource management could be implemented, including: developing alternative water supplies, reservoirs, water efficient processes, rainwater harvesting and storage, water recycling, etc.		
	• Technical modification to facilities and plant to allow operation during warmer average temperatures, dry periods and extreme events.		

4.1 Raw materials, supply chains and logistics

Risks and opportunities	Risk management options	Significance Design stage	Significance Retrofit
The fossil fuel sector is heavily reliant on marine transport and port facilities. The following list provides an indication of the climate issues likely to be significant in relation to ports and shipping facilities: • Sea levels and wave heights, • Storm tracks and storm surges, • Ambient temperatures (which affect carrying capacity) and extremes of high temperature (which can cause warping of equipment), • Sea water temperatures, acidity and salinity, • Precipitation and flood risk, • Ice extent and thickness, • Fog, mist, • Subsidence, • Winds. Unless steps are taken to adapt new and existing port developments, operators face increased risk of flooding and storm damage to assets and infrastructure, damage to electrical equipment, service disruption, and increased operating costs. Dredging operations may be affected by changes in sedimentation patterns and currents, while equipment operating thresholds (e.g. for cranes) may be exceeded during extremes of high temperature or winds.	• Given the scale of the potential climatic changes and the far-reaching consequences it would be inappropriate to use historic climatic data for the design and operation of any major new port development.		
	• Managing these risks requires an in-depth understanding of individual port and harbour sites and their estuarine / coastal location. Vulnerability can be understood through a climate risk assessment, taking account of the latest climate change scenarios.		
	• The impact of climate change on asset life, operational performance, maintenance and capital investment expenditure of port and harbour facilities should be assessed, and future climate risks should be incorporated into standard risk management procedures.		

Risks and opportunities	Risk management options	Significance Design stage	Significance Retrofit
Arctic transport routes and energy infrastructure, particularly pipelines, rely on permanently frozen ground, but are currently located across areas of high risk of permafrost thaw. Risks to assets include: • Structural failure, • Reduced access and increased transport costs due to a shorter winter season for ice roads, • Distribution problems as oil and gas pipelines fracture, • Instability in soil slopes, with greater risk of floods, mudslides, rockslides and avalanches, • Accidents and spills, contamination of land, • Weakening of open pit mine walls, • Pollutant effects as mine tailings thaw. Existing assets may require continuous repair and maintenance, with associated costs.	• New and promising fields will require significant investment in infrastructure and transport routes. The projected rate of warming and impacts on permafrost should be taken into account in the design of all new construction.		
	• Arctic infrastructure -- such as production facilities, pipelines, tanks and roads – will need to be adapted to accommodate softer ground.		

4.2 Assets, site conditions and workforce

Risks and opportunities	Risk management options	Significance Design stage	 Retrofit
Atmospheric conditions affect the power flow rating of transmission and distribution lines. The thermal rating of a line is governed by a maximum allowable conductor temperature in order to prevent excessive sagging. Higher temperatures will tend to reduce transmission capacity, heightening existing network constraints.	• National or international standards which specify thermal ratings should be revised to reflect projected changes in climate.		
	• Network upgrades, including closer pylon spacing, should be considered.		
	• Load management can help to cope with heat wave conditions: to ease pressure on the power grid some companies reimburse businesses willing to curtail daytime usage of electricity, others redirect excess power from other parts of the network, or purchase additional power from other sources.		
Many coal, oil, gas and nuclear power stations are located along the coast, and are significantly exposed to increased flooding and erosion risks due to sea level rise and increased storm surge height. There is some evidence that climate change will lead to an increase in cyclone activity and intensity and also monsoon intensity which could pose a threat to plant, particularly on some coasts.	• Siting and design of new facilities taking account of climate change. Relocation of existing facilities may be necessary in some cases.		
	• Flood and coastal erosion management strategies for existing facilities.		

4.3 Operations, processes, products and markets

Risks and opportunities	Risk management options	Significance Design stage	Significance Retrofit
Gas turbine performance is affected by hot weather through reductions in thermal efficiency and power output Increasingly high temperatures and humidity will be detrimental to electricity generation from gas, oil, or nuclear steam cycles, which rely on cooling towers for the condensing process. Cooling systems will not perform effectively in periods of extremely high temperatures, leading to reduced/deferred production and increased cooling requirements.	• Review efficiency of current gas turbine design as a function of temperature in the light of climate change data.		
	• Install turbine inlet cooling systems.		
	• Review the design basis for cooling systems as a function of climate change.		
The market impact of hotter, drier summers is already reflected in energy demand trends. Across Europe, demand peaks are increasingly aligned with summer, rather than winter, temperatures. Summer peak demand will likely be amplified in cities through the Urban Heat Island effect. Recently, Spain, Italy and the United States set new summertime records for power demand. Supply problems were widespread: the UK grid operator issued a supply shortfall warning and parts of central London were hit by blackouts; several US states suffered power cuts and supply warnings; European power grids were strained by unprecedented demand for air conditioning. These problems will worsen as global summertime temperatures continue to rise. In de-regulated systems suppliers are responsible for predicting weather conditions in order to manage supply contracts. When they fail to project accurately they are exposed to significant imbalance penalties.	• Recent heat waves highlight the need to consider climate risks in the planning of any new power stations. Technical modification to power generation plant may be possible to allow operation during warmer average temperatures and higher extremes of hot weather.		
	• Demand management strategies may help to reduce strain on power grids during hot summers.		
	• Those with responsibility for managing demand must take account of future changes in climate, particularly as global energy demand is predicted to rise. The risk of imbalance penalties can be mitigated or transferred through weather derivatives.		

4.3 Operations, processes, products and markets

Risks and opportunities	Risk management options	Significance: Design stage	Significance: Retrofit
Extreme weather events, like Hurricanes Rita and Katrina, can mean losses in oil refining capacity and consequent oil price rises.	• Plant should be designed to be resilient in the face of future, rather than historical, climate. Design should be tested for robustness against potential future increases in storminess.		

4.4 Local communities and natural environments

Risks and opportunities	Risk management options	Significance	
		Design stage	Retrofit
Reductions in rainfall will increase pressure on water resource management. Similarly, rising temperatures will increase energy demand for cooling and refrigeration. Rising sea levels and increased frequency and intensity of heavy rainfall will exacerbate flood risks. As with any large industrial facility, use of water and energy during periods of peak demand must be managed to avoid actual or perceived negative impacts to local environments or communities. If climate change exacerbates water shortages, flood risk or peak energy demand, industrial facilities may be held responsible. Any changes in pollutant pathways could also be 'blamed' on local industry.	• Engage with government and local communities on the robustness of water supplies, power supplies, and flood defence schemes in the face of climate change, to ensure power generation activities do not make local communities more vulnerable.		
	• Ensure that sufficient natural resources (especially water) are available over the lifetime of new power generation or distribution investments, taking account of: • Likely increases in demand for resources from local communities and natural environments, • Regulatory risks that may arise during low river flow conditions.		
	• Contaminated land assessments and monitoring should explore the future impacts of climate change on contamination pathways.		
	• Siting and design of new facilities taking account of climate change. Developers and operators should work with local communities to develop and implement measures to cope with risks to power supplies.		

Case study: Permafrost degradation and energy infrastructure

It has been reported recently that up to half of Russia's natural gas reserves are in danger because of climate change. Roshydromet, the Russian environment monitoring agency, has published a report warning of the dangers of permafrost thaw to the Russian energy sector, which in recent years has transformed the country into an energy superpower.

Whereas a temperature rise of 1.4ºC is expected by mid-century for the earth as a whole, in Arctic areas north of 60ºN, a 2.5ºC rise is expected. In discontinuous permafrost regions, where ground temperatures are within just 1-2ºC of thawing, permafrost will likely ultimately disappear due to climate change. In some areas, rapid thaw is already occurring.

As permafrost thaws, the consequences for energy assets include:

- Structural failure of buildings, plant and equipment,
- Distribution problems as oil and gas pipelines fracture,
- Accidents and spills, contamination of land and water,
- Slope instability, with greater risk of floods, mudslides, rockslides and avalanches,
- Reduced access and increased transport costs due to a shorter winter season for ice roads,
- Increased operating costs and unplanned capital investment to overcome the above impacts.

Existing infrastructure – such as production facilities, pipelines, tanks and roads – would have to be adapted to accommodate softer ground. Current and future exploration and development projects might require significant investment in resilient infrastructure. Transport costs would increase and new routes may be required. Those companies that do not take the projected rates of warming and impacts into account in the design and future operation of new assets and in their cash flow projections could be at risk. They may also find they have problems with the governments in the countries where they are operating if revenues are affected by increasing costs, leading to reduced concession payments.

It may be appropriate for corporate, HSE and operating risk registers for oil and gas companies in northern latitudes to track these increasing exposures and ask themselves:

- How will continuing permafrost thaw affect asset life, operational performance, maintenance and capital investment expenditure in Arctic regions?
- Are the designs of new assets taking into account the changing permafrost conditions over the anticipated life time of assets? If not who is most at risk?
- How exposed are companies if the projected climate change impacts on cash flow have not been assessed? Is there a legal liability exposure?

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Section 5

Climate risk management for **renewable power generation, supply** and **distribution**: hydroelectric, wind, wave or tidal, combustible (biomass), and solar

5.1 Raw materials, supply chain and logistics

Risks and opportunities	Risk management options	Significance Design stage	Retrofit
Biomass: Because of its reliance on agricultural production the biofuels industry is particularly exposed to climate risks which will increasingly affect the economic viability of crops over time. Cultivation of raw materials, including maize, sugar beet and sugar cane crops, can be affected by higher temperatures, changing patterns of rainfall (including drier growing seasons) and flooding. Knock-on impacts on pests, diseases and competing plants all mean that crops may no longer be viable in current locations under future climate conditions. Crops that remain viable may be of reduced quality.	• New investments or developments should take account of the agricultural impacts of climate change, including the potential for large-scale changes in rainfall.		
	• In areas which are likely to be increasingly water-stressed a number of water saving measures could be implemented, including: • Dam construction; • Irrigation systems and runoff management; and • Water harvesting to serve drier season needs.		
	• Crop diversification may reduce exposure to climatic extremes, though this must be carefully managed. Diversification into new crops with which they have little experience exposes producers to vulnerability. In addition, investment in specialist agricultural equipment constrains producers to specific crops until the capital is repaid, making it difficult to diversify.		
	• Producers could take up opportunities to plant less water-intensive and more heat- and drought-tolerant crops. • Salt tolerant crops may also be desirable. • Many temperate crops require winter chill or vernalisation though in some cases this can be simulated through chemical treatments.		
Wind energy: Wind patterns (wind speed and direction) may change, affecting the economic viability of wind energy facilities.	• Siting of facilities should consider the robustness of facilities to potential changes in wind speed and direction due to climate change.		

5.1 Raw materials, supply chain and logistics

Risks and opportunities	Risk management options	Significance Design stage	Retrofit
Solar energy: Output is affected by cloud cover, which in turn is dependent on wind shear, humidity, temperature and precipitation. Climate change induced changes in these variables could affect the performance of solar panels and seasonal output of solar energy generation.	• As with all weather-driven renewable fuels, project site and design decisions should take account of the likely impacts of climate change in order to optimise available solar energy.		
Hydropower: While precipitation is projected to increase on a global level, many parts of the world are expected to see significant drying during some seasons. Studies indicate that declining river flows as a result of climate change will lead to declining hydropower production. For example, the IPCC's Fourth Assessment Report points to a 25% decrease in hydropower capacity at existing stations in Spain by the 2070s. Hydroelectric facilities fed by glacial meltwater have historically benefited from the ability of glaciers to regulate and maintain water levels of rivers and streams throughout the summer – a time when precipitation-fed water courses often run low or dry. With rising temperatures glaciers are shrinking. Late summer reductions in the water levels of glacier-fed streams and rivers have also been documented. As glaciers recede and glacial ice diminishes, the reservoirs that 'feed' many hydroelectric facilities are diminishing.	• Hydroelectric schemes are designed for a particular river flow distribution. New stations should be designed to accommodate changes in flow characteristics as a result of climate change. Existing facilities may need to be modified as flow characteristics change.		
	• As the capital costs of hydropower are relatively high and payback periods long, investors will need to consider the location and design of new hydropower generating facilities, taking account of climate change.		

5.2 Assets, site conditions and workforce

Risks and opportunities	Risk management options	Significance Design stage	Significance Retrofit
All renewables: Renewable energy infrastructure is as exposed to climate risk as other large industrial projects. Large fixed assets are vulnerable to flooding, subsidence, erosion, and potential increases in storminess. Climate change presents a challenge to the optimal design, development and operation of these facilities.	• Design standards should be revised to reflect projected climatic changes rather than historical data. This might require changes to design loads or to minimum stated levels of service.		
	• Monitoring systems should be used to detect or predict in-service problems.		
	• Inspection and maintenance regimes for various components of the infrastructure should be reviewed.		
	• Margins of safety should be reviewed to assess whether existing structures require modification to maintain adequate levels of safety and serviceability in the face of a changing climate.		
Wave/tidal energy: Climate change will increase global sea levels as a consequence of thermal expansion of the oceans and increased melting of glaciers over land. In many coastal regions large tidal variations, cyclonic activity, and extreme rainfall events are common, resulting in coastal and inland flooding. The expectation of stronger cyclones in some regions in coming decades, combined with the potential for significant increases in regional rainfall, suggest the potential for increased coastal hazard. Wave or tidal energy plant is built to specific design thresholds, though these generally do not take account of the potential changes in frequency and intensity of storm events due to climate change.	• Design thresholds should be examined for their robustness to potential changes in the frequency and intensity of extreme events.		
	• Margins of safety with respect to storms, wind strengths and flooding should be developed with climate change in mind. Existing plant should be assessed to see whether modifications are required to maintain adequate levels of safety and serviceability in the face of a changing climate.		
	• Current inspection and maintenance regimes for assets and infrastructure should be reviewed. This review should take into account the potential changes in the frequency and intensity of extreme weather events.		

5.3 Operations, processes, products and markets

Risks and opportunities	Risk management options	Significance Design stage	Significance Retrofit
Wind energy: Wind turbines are designed and built according to prevailing climate conditions and can extract energy over a defined range of wind speeds. Outside this range the speed is either too low to allow the blades to turn efficiently or so high that the turbine shuts down in order to prevent damage from excessive gusts.	• Plant should be designed to be resilient in the face of future, rather than historical, climate. Designs should be tested for their robustness to potential changes in wind speed and direction.		
Hydropower: The benefits of projected seasonal increases in precipitation (in some locations) are limited by a hydropower facility's ability to harness increased flows, which is in turn dependent on sufficient turbine capacity or storage. Silting of hydropower dams may accelerate due to increased risk of erosion, with knock-on impacts for operating expenditure.	• Hydropower plant should be designed to take advantage of any projected seasonal increases in precipitation.		
	• Facilities should be designed to harvest and reuse overflow water during heavy precipitation events.		
All renewables: As ambient air temperatures rise and the risk of heat waves increases, demand for energy for cooling will increase. Air conditioners and refrigeration systems discharge hot air outside, adding more heat to ambient air, and furthering the need for cooling. This cycle places great strain on the energy distribution system, and can lead to neighbourhood and city-wide blackouts or brownouts. There is likely to be increased demand for renewable energy supplies which can reduce the stress of peak loads on fossil-fuel generation facilities.	• In order to exploit this potential opportunity, developers and operators must provide robust infrastructure for renewable power generation, supply and distribution which is resilient in the face of climate change.		
	• Design of new infrastructure should take account of a changing climate. Existing infrastructure may require modification to cope with a changing climate.		

5.4 Local communities and natural environments

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Risks and opportunities	Risk management options	Significance Design stage	Significance Retrofit
Biomass: The use of maize and other food crops as biofuel can drive up food commodity prices, making it difficult for local communities to feed themselves. The clearing of land for biofuel crops can result in deforestation, eroded soils and polluted water courses. There is a risk that biofuel production could affect international food prices and livestock farming margins.	• Companies and investors aiming to capitalise on the biofuels boom must ensure that plans take potential risks into account, and ensure that competition with local communities and natural environments are minimised.		
Hydropower: The water in hydropower reservoirs is often used for other purposes beyond energy generation, including irrigation, flood control, transport, and domestic or industrial consumption. Any decrease in seasonal rainfall creates potential for competition with the local community's demand for water.	• Engage with government on robustness of water resources in the face of climate change, to ensure hydropower schemes do not make local communities more vulnerable.		
	• Ensure that sufficient water resources are available over the lifetime of new hydropower investments, taking account of likely increases in demand for resources from local communities.		
	• Owners and operators of hydropower projects must balance the conflicting objectives of power generation, safety, water quality and habitat.		

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Section 6

Climate risk management for the **tourism** sector

6.1 Raw materials, supply chains and logistics

Risks and opportunities	Risk management options	Significance: Design stage	Significance: Retrofit
This sector is dependent on the resources (both natural and man-made) that draw people to visit. Climate change impacts on these resources will increase the risks to the industry. The following are some examples:	• Management of both man-made and natural attractions should take account of the likely impacts of climate change.		
• Warmer temperatures and a decline in frost periods will mean shorter snow seasons and a reduction in snow cover. Winter sport resorts may be adversely affected.	• Ski resorts and other seasonal destinations could be marketed as all-year attractions with a diverse mix of activities to ease pressure on resources and infrastructure and broaden income base. This follows the example of Whistler in Canada, a centre for skiing in winter which is also promoted as a mountain biking and walking destination in the summer.		
• Coastal tourism is vulnerable to rising sea levels and storm surges, resulting in detrimental pressure on beaches, paths, coastal properties and amenity areas.	• In the face of climate change visitor facilities may need to be upgraded to ensure a continued 'quality of experience' under different climatic conditions.		
	• Coastal management strategies such as managed realignment (which involves breaching an existing coastal defence and allowing the land behind to be flooded by the incoming tide) or the introduction of new hard coastal defences may be required.		

6.1 Raw materials, supply chains and logistics

Risks and opportunities	Risk management options	Significance: Design stage	Significance: Retrofit
• Fragile or unique ecosystems (e.g. the Great Barrier Reef, mountain gorilla habitats) are extremely susceptible to the impacts of climate change. • Changes in all climatic variables, in particular higher temperatures and changing rainfall patterns, will affect species distribution, with knock-on impacts on pests, diseases and competing species.	• The promotion of visitor resources in more resilient locations though within the same area could relieve pressure on the most vulnerable ecosystems.		
	• Understanding the interactions between climate change, visitor behaviour and environmental capacity is vital. Tourism policy should recognise the interdependence of the tourism industry and key ecosystems, and work to ensure that their use as a visitor resource is sustainable.		
• Cultural heritage features and archaeological sites are particularly vulnerable to coastal erosion, driving rain, forest fires, and poor air quality episodes during sustained periods of hot weather.	• Monitoring will be necessary to identify signs of deterioration. The effects of a changing climate on older buildings will require planning and funding for additional maintenance.		
	• Management frameworks must ensure that visitor pressure does not exacerbate climate-related pressures.		

6.1 Raw materials, supply chains and logistics

Risks and opportunities	Risk management options	Significance Design stage	 Retrofit
The tourism industry is water intensive. The availability and management of this climate-sensitive resource, particularly in hot weather when demand for water is highest, is critical to the profitability of this sector. Sports and recreational fishing could suffer in dry summers. In some locations during some seasons there may be insufficient water to maintain inland canal navigation. In some locations there may be insufficient water to continue golf course irrigation. Low summer river flows could also affect the attractiveness of waterside commercial leisure developments. Lower river flows may increase pollutant concentrations and thus reduce their attractiveness to visitors and create potential health problems.	• A range of actions and techniques available to increase adaptive capacity, including: • Abstraction controls and licensing; • Creative use of waste water from treated sewerage; • Tighter water efficiency standards; • Water efficient fixtures and fittings; • Xeriscaping, or low-water planting; • Water reclamation and reuse; and • Managing point source pollution.		
	• Building design should take account of potential future water constraints, through use of grey water recycling and other water conservation practices.		

6.1 Raw materials, supply chains and logistics

Risks and opportunities	Risk management options	Significance: Design stage	Significance: Retrofit
Transport networks and supply chains are vulnerable to disruption from flooding, storminess and erosion. During sustained periods of hot weather, speed restrictions can be imposed on rail transport. Chill chains (whereby frozen or perishable products are chilled from producer to consumer) are also at risk during hotter weather.	• Storage and chill chain systems should be reviewed to reflect projected climatic extremes rather than historical data, in order to maintain the quality of products and reduce risk of spoilage.		
	• Margins of safety, for example regarding wind strengths should be reviewed to assess whether existing structures require modification to maintain adequate levels of safety and serviceability in the face of a changing climate.		
	• Current inspection and maintenance regimes for various components of transport infrastructure should be reviewed. This review should take into account the likely changes in ambient in-service conditions as well as the frequency and intensity of extreme weather events.		
	• Monitoring systems can be used to detect or predict in-service problems.		
There are regulatory risks associated with land contamination, air pollution and water pollution following a major storm event, e.g. Hurricane Katrina.	• Environmental policy and emergency management plans should take account of the impact of a changing climate and the potential impacts of increased frequency and intensity of storms on pollutant pathways.		

6.1 Raw materials, supply chains and logistics

<table>
<tr><th rowspan="2">Risks and opportunities</th><th rowspan="2">Risk management options</th><th colspan="2">Significance</th></tr>
<tr><th>Design stage</th><th>Retrofit</th></tr>
<tr><td rowspan="4">The tourism sector is heavily reliant on large and uninterrupted supplies of energy. Power generation, distribution and demand are highly exposed to climate risks (see Sections 4 and 5 for a full discussion), through:
• Potential damage to infrastructure by subsidence, flooding, and storms,
• Reduced performance of underground cables due to higher temperatures and drier soils,
• Reduced efficiency in gas turbines due to higher air temperatures and lower air density, and
• Lack of cooling water for generation plant.
When temperatures are hottest and energy demand is highest, extra pressure is put on the generation network.</td><td>• Large scale developments should consider potential risks and plan for a robust infrastructure that will support sustainable use of the development over its lifetime.</td><td></td><td></td></tr>
<tr><td>• Operators should reduce the energy demand of a facility through passive design techniques, such as shading and ventilation, cool materials, or heavyweight building materials.</td><td></td><td></td></tr>
<tr><td>• Any new cooling or lighting should be low energy, in line with emissions reductions targets.</td><td></td><td></td></tr>
<tr><td>• Infrastructure should be reviewed to assess sensitivity of design to changes in climatic conditions. Provision should be made for enhanced maintenance regimes.</td><td></td><td></td></tr>
</table>

6.2 Assets, site conditions and workforce

Risks and opportunities	Risk management options	Significance: Design stage	Significance: Retrofit
There is potential for damage to accommodation, attractions or facilities through increased rates of coastal erosion, sea level rise, storm surges, and flooding after heavy rainfall. As well as damage to assets and building contents, flooding can create access problems. Some properties may become uninsurable if they are in flood-prone areas. Coral bleaching and mortality associated with climate change is a particular concern in areas where reefs have historically provided a measure of protection against coastal flooding and inundation.	• Flood risk assessments should identify land at risk and the degree of risk.		
	• Design and location of assets should take account of changing flood risk.		
	• New development should be directed away from flood risk areas. Owners and planning authorities should take opportunities to relocate existing buildings that will be vulnerable in future to flooding.		
	• Land that is required for current and future flood risk management should be safeguarded.		
	• Flood resilient design and materials, such as raised floor levels, widened drains, and temporary flood barriers, should be incorporated at the design stage or during upgrades or refurbishment.		
	• In high risk areas, ground floor spaces can be used for public open space, while accommodation and storage of goods and materials might be relocated to higher levels.		

6.2 Assets, site conditions and workforce

Risks and opportunities	Risk management options	Significance Design stage	Significance Retrofit
Higher temperatures will lead to increased demand for cooling in visitor facilities (e.g. hotels, restaurants, shops), particularly within high density areas where the Urban Heat Island effect is most pronounced. Hotter temperatures will also create demand for urban greenspace, open water and water features, open spaces and shading. Climate change presents developers with significant opportunities to design or remodel outdoor spaces and buildings that are attractive to visitors in the future climate.	• The demand for building comfort (e.g. requirements for cooling under hotter summer conditions) could increasingly be met through innovative building techniques and thermally efficient properties, rather than energy-dependent devices such as air-conditioners.		
	• An obvious adjustment to hotter weather is to open windows and doors to let cooler air replace hotter inside air. This may result in knock-on impacts, such as greater risk of crime, noise and pollution. In addition to planning, design and technological solutions, lateral thinking will be important for managing knock-on risks.		
	• Greenspace and trees offer ways to cope with hot weather (through shading and evaporative cooling), but are themselves vulnerable to decreased water availability, rising temperatures, and changing patterns of disease and pests.		

6.2 Assets, site conditions and workforce

Risks and opportunities	Risk management options	Significance Design stage	Significance Retrofit
The tourism industry employs large numbers of outdoor workers who will be increasingly susceptible to heat stress during sustained periods of hot weather. On cloudless days outdoor workers are exposed to UV radiation, and higher temperatures can increase production and concentrations of air pollutants which exacerbate respiratory disorders. Through contact with visitors from around the globe, tourism workers are also likely to be more exposed to viruses and infections.	• Employers should raise awareness of the potential increased risks to health from climate change, and undertake risk assessments for employees.		
	• Employers should provide advice on staying cool in hot weather, protection against sun exposure and safeguarding health when exposed to infectious diseases.		
	• Health and safety legislation in Australia obliges employers to provide a safe working environment, with includes sun protection measures for outdoor workers.		
	• Some workers may be able to change working hours to cooler times of day.		

6.2 Assets, site conditions and workforce

Risks and opportunities	Risk management options	Significance Design stage	Significance Retrofit
Increased intensity of precipitation will lead to more rain penetration around openings in buildings or service infrastructure, affecting the structural integrity and value of the asset. More intense rainfall events could mean drainage systems (including roof drainage, sewer systems, carriageway drainage etc) are less able to cope, resulting in flash floods in urban areas.	• Potential impacts of incremental changes in precipitation and extreme events on infrastructure should be reviewed and appropriate risk assessments should be undertaken.		
	• Analysis of both location and asset design will be important aspects of climate-proofing tourism property investments.		
	• Structural solutions like rainproofing, wide roof overhangs, and using resilient building materials can reduce risks.		
	• Operators and owners should ensure that flood pathways are managed to cope with heavy rainfall events. Sustainable drainage systems (SuDS, which allow water to soak gradually into the ground), and wider drains can reduce the risk of flash flooding.		
River or canal navigation may be difficult to sustain through periods of low water flow.	• Conservation of water through abstraction controls and increased storage of water within a catchment during wetter seasons when supplies are plentiful to augment low flows during summer shortages can reduce likelihood of low flows.		
	• Engineering solutions like dredging, decreasing lockage volume, back pumping at locks, or water transfer to augment resources, may be appropriate.		

6.2 Assets, site conditions and workforce

Risks and opportunities	Risk management options	Significance Design stage	Significance Retrofit
Subsidence and heave risks are expected to increase for clay soils, due to higher temperatures, lower summer rainfall, and increased evapotranspiration. Resulting impacts can affect the performance and value of assets and infrastructure, including hotels, airports and other tourist facilities.	• A range of monitoring actions and engineering techniques are available to increase resilience to subsidence and heave, including: • Ground monitoring, • Re-grading and reinforcement of slopes, • Deeper, stronger, better drained retaining structures, • Vegetation management, • Moisture control systems or soil rehydration, • Infill of foundations and underpinning, and • Deeper, stronger foundations.		

6.3 Operations, processes, products and markets

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managing your climate risks

Risks and opportunities	Risk management options	Significance Design stage	Significance Retrofit
Decisions about holiday destination and timing are affected by weather and climate at potential holiday locations and at home: • As some regions become hotter and drier (e.g. southern Spain and Greece) they may become less attractive as summer holiday destinations but more attractive during other seasons. • Consumers may take advantage of a warmer climate by staying at home during traditional summer holiday periods.	• Developers and operators should take advantage of opportunities to market new destinations or attractions, though it is essential that this is done in a managed way that does not hinder the local community's ability to adapt to climate change.		
There are market opportunities for new or non-traditional holiday destinations as climate changes.	• To exploit this potential, operators must maintain a high quality environment, efficient transport systems and sufficient capacity to cope with a rise in tourist numbers, all of which will be vulnerable to climate risks.		
The infrastructure that supports the tourism sector (e.g. transport, power and communication networks, drinking water and irrigation systems) may perform poorly and/or require unplanned additional maintenance due to changes in temperature, sea levels or precipitation. Infrastructure is also vulnerable to extreme events, such as river or coastal floods, wild fires and storms.	• Infrastructure should be reviewed to assess sensitivity of design to changes in climatic conditions.		
	• Provision should be made for enhanced maintenance regimes.		
	• Relevant codes and standards should be amended to reflect projected climatic conditions.		

6.3 Operations, processes, products and markets

Risks and opportunities	Risk management options	Significance Design stage	Significance Retrofit
There is a risk of higher incidence of food poisoning as increasing temperatures result in higher levels of bacteria and other pathogens.	• Existing food hygiene practices should be reviewed to take account of higher temperatures.		
	• Staff will need to be prepared to deal with any food poisoning or infection outbreak.		

6.4 Local communities and natural environments

Risks and opportunities	Risk management options	Significance Design stage	Retrofit
In locations and seasons where water supplies are currently scarce or just adequate, climate-related reductions in rainfall will increase pressure on water resource management. Water use by the tourism sector could be held responsible for negative impacts on local environments or communities. • There is potential for conflict between the tourism sector's water demands and the local community's need for domestic or irrigation water supplies. • Excessive drawdown on well water can lead to saline intrusion into groundwater. • Low river flows have less capacity to dilute effluent discharge, with adverse effects for the local community's water quality. These conflicts are most likely to happen during very hot weather, when demand for water is highest and supplies are lowest.	• Developers and operators should engage with government on robustness of water resources in the face of climate change, to ensure tourism activities do not make local communities more vulnerable.		
	• Developers and operators should ensure that sufficient natural resources (especially water) are available over the lifetime of new tourism investments, taking account of: • Likely increases in demand for resources from local communities, • Regulatory risks that may arise during low river flow conditions.		
	• Water balance modelling should take account of climate change impacts on water resources (surface and ground water), and of the impacts of climate change on other water users.		
	• Contaminated land assessments and monitoring should explore the future impacts of climate change on contamination pathways.		
	• Review the ability of water treatment plant to cope with lower water quality at times of low flow, taking account of climate change projections.		

6.4 Local communities and natural environments

Risks and opportunities	Risk management options	Significance Design stage	Retrofit
During sustained periods of hot weather, demand for energy for cooling and refrigeration in tourist facilities can aggravate power supply problems for the local community.	• Gradual increases in temperature and changes in heatwave frequency and severity should be taken into account during infrastructure reviews and appropriate risk assessments should be undertaken.		
	• Developers and operators should work with local communities to develop and implement measures to cope with risks to power supplies.		
Tourist facilities, with large expanses of impermeable ground cover, may accelerate run-off during increasingly heavy rainfall events and exacerbate flash flood risk for local communities.	• Developers and operators should engage with local authorities on climate change implications for infrastructure.		
	• Design of assets and infrastructure should take account of changing climate variables, incorporating water storage, increased drainage capacity, Sustainable Drainage Systems (SuDS which allow water to soak gradually into the ground,) etc, to ensure facility does not impair the sustainability of local communities or natural environments.		

7. Further information

- Intergovernmental Panel on Climate change (IPCC) Fourth Assessment Report, 2007. (www.ipcc.ch)
- UK Climate Impacts Programme (www.ukcip.org.uk)
- UK Met Office (www.metoffice.gov.uk)
- Arctic Climate Impact Assessment (ACIA) Scientific report, 2004 (www.acia.uaf.edu)
- Turbine Inlet Cooling Association (www.turbineinletcooling.org)
- World Bank Group – Global Environment Facility (GEF) Program (www.gefweb.org)
- Acclimatise (www.acclimatise.uk.com)
- Global Framework for Climate Risk Disclosure (www.ceres.org)
- Climate Change and the Visitor Economy: the challenges and opportunities for England's Northwest (www.snw.org.uk/tourism)
- Climate change impacts and adaptation cross regional research programme (www.defra.gov.uk/environment/climatechange/)
- Climate change and human health: risks and responses, World Health Organisation (www.who.int/globalchange/)