HS2

Climate Change Adaptation and Resilience

Adaptation Reporting Power (ARP) Report

December 2021

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Front cover image: Visualisation of HS2's Curzon Street station in Birmingham.

Executive summary

HS2 and adapting to climate change

High Speed Two (HS2) will be the spine of the UK transport network. HS2 is being designed to operate into the 22nd century and our responsibilities include making sure the railway is resilient to our changing climate. HS2 must be able to withstand climate change now and in the future including more frequent extreme hot and cold weather, heavy rain, high winds and storms. We are building a rail network that is climate resilient for the long term.

The Climate Change Act 2008[1] established the Adaptation Reporting Power (ARP) which allows the Government[2] to ask key organisations to report on the steps they are taking to prepare for climate change. We are submitting our first ARP report under the third round of reporting, responding to the risks identified in the UK's second Climate Change Risk Assessment published in 2017. Our adaption report includes the Phase One route between London and the West Midlands and Phase 2a between the West Midlands and Crewe, which have been approved by Parliament and are in the construction and design stages respectively.

This is the first ARP report for a stand-alone project that is still in the design and construction stage. It highlights our progress so far, identifies our ongoing work and will be used both internally and by external stakeholders to encourage engagement and support for adaptation and resilience including in the construction and transport sectors. It shows our commitment to being an exemplar for the industry. As part of our HS2 Learning Legacy, we are sharing how we are already embedding climate change adaptation and resilience into HS2 and the lessons we are learning as we build a high-speed railway that will transform Britain.

Our assessment of climate resilience risk

This report is based on results from our risk assessments from the planning and consent stages for Phase One and Phase 2a. It also demonstrates our work in the design and construction stages to further assess potential climate change impacts. The risk assessments in our Environmental Statements for Phase One[3] and Phase 2a[4] included setting out the potential impacts of climate change on our infrastructure and assets using the UK climate change projections available at the time, UKCP09.

HS2 is being designed and built to be resilient to impacts from weather events and climatic conditions. We have developed standards based on best practice engineering codes and we have adapted them to consider climate change where appropriate. Our work in this area is presented in this report.

This report summaries the results of our climate change risk assessments and examples of our adaption and resilience measures. It presents potential risks to HS2 and adaptation actions that we have embedded into our design to reduce or mitigate the risks.

Without considering adaptation actions, we know climate change could affect HS2 through:

- **construction impacts** – resulting in programme delays and/or compensation and associated costs;
- **operational impacts** – including less resilient landscape and biodiversity features, impacts on performance and service levels, and reputational impacts; and
- **financial costs** – programme delay costs and operational costs.

1 **legislation.gov.uk/ukpga/2008/27/contents**
2 Secretary of State for the Department of Environment, Food, and Rural Affairs (Defra).
3 **assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/259614/Volume5_Climate_Change_Resilience_Report_CL-003_000.pdf**
4 **assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/627020/E33_CL-002-000_WEB.pdf**

Executive summary

We recognise that climate change resilience is about more than just the 'hard' infrastructure that we are building. When HS2 affects the environment, it is important that resilience is also considered. We consider the impacts of climate change, in combination with the impacts of the railway, in all stages of the Project. We consider potential in-combination impacts for communities, business and the natural, historic and built environment along the route.

For example, we are integrating resilience into HS2's Green Corridor – the largest single environmental project in the UK[5] – to make sure the environment alongside HS2 is managed with climate adaptation and resilience in mind. In particular, the Colne Valley western slopes project[6] will transform an HS2 construction site into one of the largest areas of new chalk grassland in the Chiltern Hills.

Our work on climate adaptation and resilience

HS2 is designed in line with our standards, which are built on best practice engineering codes and adapted to consider climate change where appropriate. Our own standards for climate change adaptation and resilience set out requirements that contractors must comply with. In particular, this requires contractors to produce a Climate Change Adaptation and Resilience Report reviewing information provided in our Climate Change Design Impact Assessment and Climate Change Resilience and Interdependencies Assessment. We also use recognised environmental sustainability standards BREEAM (Building Research Establishment Environmental Assessment Method) and CEEQUAL (the Civil Engineering Environmental Quality Assessment and Award Scheme) for assessing the design and construction of all our stations, depots, control centre and infrastructure works with climate change adaptation and resilience credits being targeted.

To protect the HS2's infrastructure during construction, our Code of Construction Practice (CoCP) for Phase One and Phase 2a have requirements that reduce risks from extreme weather and associated conditions. We are also managing in-combination climate change impacts, especially managing water to ensure resilience against drought conditions while providing benefits such as reducing greenhouse gas emissions. An example of this is set out in one of our case studies (**page 30**, 'Construction in the Chilterns').

We are also working with industry and academic partners to develop our understanding of climate change adaptation and resilience. We will leave a learning legacy for future projects and infrastructure operators and are committed to including climate adaptation and resilience lessons in this process.

Our operational planning will continue to ensure we are ready to manage risks from climate change once services are operating. We are working with our partners, our supply chain and stakeholders to achieve our climate change adaptation and resilience objectives. This will ensure we play our part in helping the UK's transport sector to enhance its climate resilience.

Our work to deliver on climate adaptation and resilience is ongoing and is set out in the final section of our report. We will use this to measure our progress in future climate adaption and resilience reporting rounds.

5 **assets.hs2.org.uk/wp-content/uploads/2020/12/11152821/24136_HS2_GreenCorridor_v43_CS1469_Interactive.pdf**

6 **hs2.org.uk/in-your-area/local-community-webpages/hs2-in-hertfordshire/colne-valley-western-slopes/**

Introduction

1.1 Overview of HS2

High Speed Two (HS2) is a new, low carbon rail network for the UK. Dedicated lines for high-speed, intercity travel will increase rail capacity and combat congestion on the existing network by freeing up space for local trains, commuter services and rail freight. HS2 will improve connections between the Midlands and the North, driving new investment and job opportunities. At peak construction, the Project will support more than 34,000 jobs.

HS2 is playing an important part in the UK's move to a net zero economy. It will offer low carbon journeys from day one of service, making HS2 more sustainable for long-distance trips than conventional cars and aircraft. As Britain's first new intercity railway north of London in 100 years, HS2 is being designed with our future in mind. We are making sure the service will be climate resilient and our work on adaptation is the focus of this Adaptation Reporting Power (ARP) report.

Our company, HS2 Ltd, is wholly funded by the Secretary of State for Transport, represented by the Department for Transport (DfT). It is a Non-Departmental Public Body and is treated as part of the central government sector by the Office for National Statistics.

HS2 Ltd was established by the DfT to develop, build and promote the new high-speed railway. Our responsibilities include developing sustainable proposals for the route; working with the DfT to secure the Parliamentary approvals and powers for the railway; and building HS2. Our ambition is to build the most sustainable high-speed railway in the world.[1]

1.1.1 Building HS2

The high-speed rail network is being built in stages. Phase One is already under construction and will connect the West Midlands and London. High-speed trains will travel between a new HS2 terminus at Birmingham Curzon Street and a new HS2 station at Euston in just 45 minutes. From Birmingham, Phase One continues north and links to the West Coast Main Line (WCML) at Handsacre, Staffordshire. Along the route, we are building more than 32 miles of tunnels to reduce the railway's environmental impact and are also creating more than 33 square kilometres of new woodland, wildlife, and river habitats. Services are due to start between 2029 and 2033.

Phase 2a was approved by Parliament in 2021 and will extend HS2 from Fradley, in Staffordshire – north of Birmingham – to Crewe. Building the 36-mile route will support 6,500 jobs and connect HS2 with the WCML south of Crewe.

Phase 2b extends the railway north of Crewe into Manchester and from the West Midlands to the East Midlands. The **Integrated Rail Plan** outlined how HS2 services will run further North from the East Midlands towards Yorkshire on existing, upgraded track. We expect to deposit the hybrid Bill for the line from Crewe to Manchester in 2022. Phase 2b does not fall in the scope of our ARP report.

1 **hs2.org.uk/building-hs2/sustainability-and-environment/hs2-and-the-natural-environment/**

Introduction

1.1.2 Our strategy

We are responsible for making sure HS2 is:

- designed, built and then operates to the highest safety standards;
- built and operates sustainably and responsibly and that we respect the communities, wildlife and places it affects; and it is
- easy to use for all passengers, reliable and integrated with existing transport systems.[2]

We know that adapting to climate change is crucial to the resilience of HS2 and affects the operation of the railway, our customers, local communities and the environment. For this reason, climate adaptation is at the heart of our company strategy.

Our Environmental Policy[3] sets out our commitment to build a high-speed railway network that is resilient to climate change for the long term. This policy provides a framework for environmental protection and management for the Project. It fulfils the environmental commitments established through our Sustainability Policy[4] and our strategic goal of creating an environmentally sustainable solution (see the table below).

The five objective areas set out in our Environmental Policy[5]

	**Green corridor:** create a green corridor for both nature and people that will conserve and enhance habitats, seek to achieve no net loss in biodiversity while designing mitigation to integrate into the character of the landscape.
	**Climate change:** build a network that is resilient for the long term, minimise the carbon footprint of HS2 and deliver low carbon, long distance journeys that are supported by low carbon energy.
	**Community experience:** manage the impact of HS2 construction and operation on people and the environment including effects from air pollution, flooding, noise and vibration.
	**Historic environment:** reduce harm to the historic environment and deliver a programme of heritage mitigation including knowledge creation through investigation, reporting, engagement and archiving.
	**Responsible consumption and production**: promote circular economy principles, responsibly source and make efficient use of sustainable resources, reduce waste and maximise the proportion of material diverted from landfill.

2 **staging.hs2.org.uk/why/about-us/our-governance**
3 **assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/850372/Environmental_Policy__P03___signed_.pdf**
4 **assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/925700/Sustainability_Policy_P06.pdf**
5 **assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/850372/Environmental_Policy__P03___signed_.pdf**

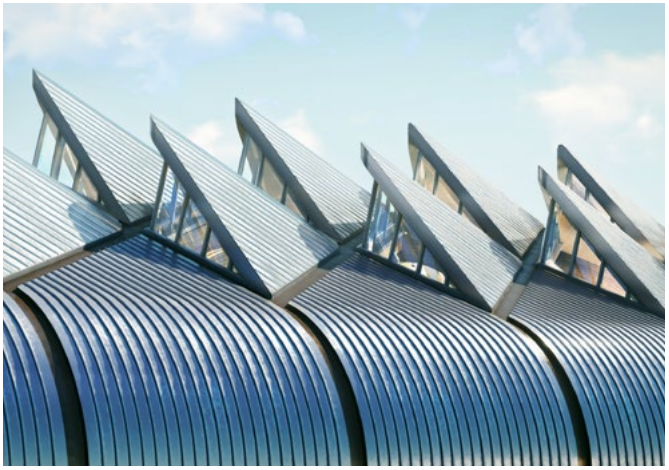
Introduction

1.2 Climate change adaptation and resilience

1.2.1 International and national context

We are submitting our first ARP at a time of heightened national and international focus on climate change adaptation and resilience. They include the following developments.

- The 26th United Nations Climate Change Conference of the Parties (COP26) was held in Glasgow in 2021,[6] bringing parties together to accelerate action towards the goals of the Paris Agreement[7] and the United Nations Framework Convention on Climate Change.[8] Adaptation and resilience is one of COP26's five priority focus areas.
- Significant new climate change evidence has been published in 2021, including the Climate Change Committee's Independent Assessment of UK Climate Risk: Advice to Government for the UK's third Climate Change Risk Assessment (CCRA3)[9] and the first part of the United Nations Intergovernmental Panel on Climate Change's sixth assessment report on climate science.[10]
- The Government has outlined its objectives for climate change adaptation in strategic plans including its Net Zero Strategy,[11] the Ten Point Plan for a Green Industrial Revolution,[12] the National Infrastructure Strategy[13] and the 25 Year Environment Plan.[14]



HS2 Interchange will be one of the world's most environmentally-friendly stations. We created a 360° virtual exhibition of Interchange for COP26. Take a tour of the future **here**.

6 **ukcop26.org**
7 **unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement**
8 **unfccc.int/resource/docs/convkp/conveng.pdf**
9 **theccc.org.uk/wp-content/uploads/2021/07/Independent-Assessment-of-UK-Climate-Risk-Advice-to-Govt-for-CCRA3-CCC.pdf**
10 **ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Full_Report.pdf**
11 **assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1033990/net-zero-strategy-beis.pdf**
12 **assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/936567/10_POINT_PLAN_BOOKLET.pdf**
13 **assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/938539/NIS_Report_Web_Accessible.pdf**
14 **assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/693158/25-year-environment-plan.pdf**

Introduction

1.2.2 Achieving net zero and staying resilient

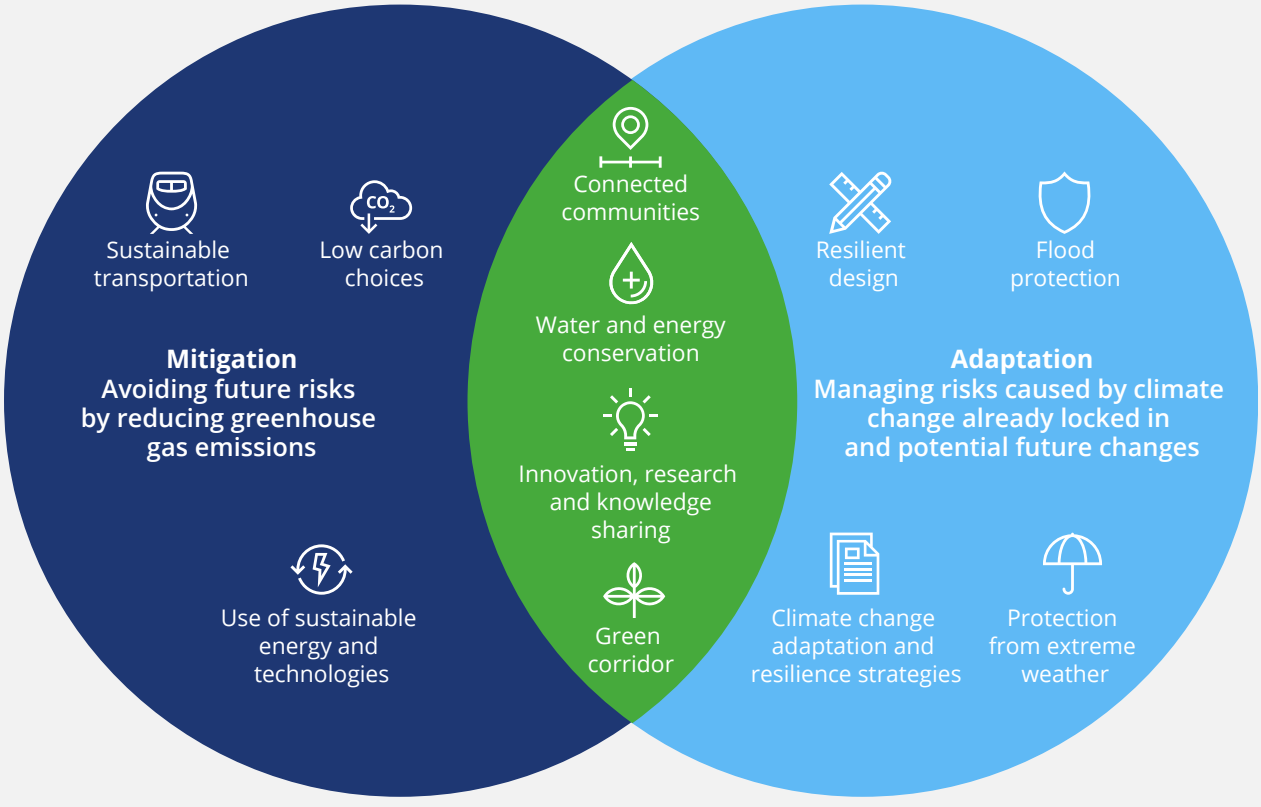
Even if all greenhouse gas emissions stop today, the world will still warm, bringing extreme weather such as floods and heatwaves. Planning to adapt to these conditions and developing pathways to reduce emissions takes time, especially for major infrastructure projects that include both the built and the natural environments. We need to act now to avoid 'locking in' high levels of risk. We can do this through mitigation and adaptation (see infographic below).

Globally, we need to reduce emissions to achieve a net zero future but do so in a way that means we are resilient to potential future changes. At COP26, the concepts of 'resilient net zero' and 'net zero adaptation' were widely discussed, recognising the need for both adaptation and mitigation to be achieved in harmony. We support these concepts, and where possible, we consider adaptation and mitigation together. HS2 will support the UK in moving to a net zero economy.

Like all infrastructure, HS2 needs to be climate resilient so it can function in a future where we may see warmer and wetter winters, hotter and drier summers, and more extreme weather. As we plan and build HS2, we are making sure we manage climate change risks and impacts.

Considering adaptation and mitigation together gives us opportunities to deliver co-benefits to the Project. We can maximise opportunities to reduce carbon and simultaneously improve climate resilience. For example, our initiatives associated with water and energy conservation reduce our carbon footprint while also making us more resilient to drought and cascading failures from interdependent infrastructure. Our Green Corridor project, which includes planting more than seven million trees and shrubs along Phase One, will create climate-resilient landscapes and boost ecology while providing opportunities to sequester carbon. Our mitigation and adaptation work has also created opportunities to innovate, research and share knowledge.

Climate change mitigation, adaptation and co-benefits

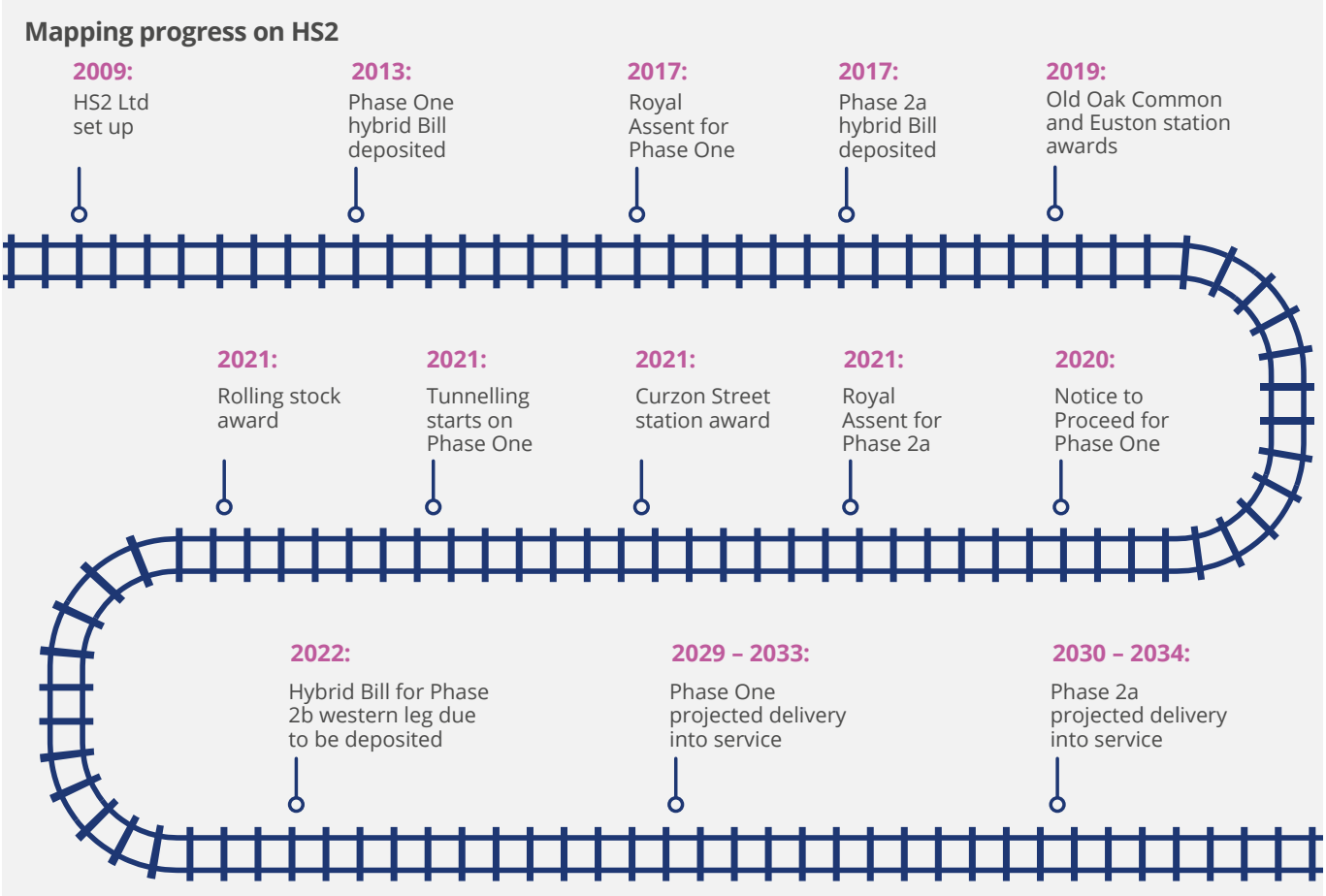


Introduction

1.3 Submitting our first Adaptation Reporting Power report

The Climate Change Act 2008[15] established the Adaptation Reporting Power (ARP). The ARP allows the Government[16] to ask key organisations to report on the steps they are taking to prepare for climate change. There have been two cycles of adaptation reporting in the past decade and the UK is now in the third round of reporting (ARP3).

This is the first ARP report for a stand-alone project that is still in the design and construction stage. We have decided to publish it before we are operational (timescale below) because climate adaptation and resilience is a fundamental part of our planning consent, design and construction programme. Climate resilience work has not been undertaken on a project of HS2's size before in the UK. We aim to be an example of good practice and we are committed to sharing how we are embedding climate change adaptation and resilience into the design and construction stages of HS2 and lessons we are learning.



15 **legislation.gov.uk/ukpga/2008/27/contents**
16 Secretary of State for the Department of Environment, Food, and Rural Affairs (Defra).

Introduction

1.3.1 Scope of our adaptation report

Each phase of HS2 (**see 1.1**) goes through a series of project stages from planning and consent to design, construction and operation. This report focuses on the design and construction stages. Climate consideration within the planning and consent stages are detailed in our Environmental Statements. This report covers Phase One and Phase 2a. Future phases of HS2 and operational aspects will be included in our ARP reports as the planning and design process progresses.

Our climate change risk assessment (**section 4**) is based on the UK Climate Change Projections 2009 (UKCP09). These were the latest projections available to us when we undertook our high-level climate change risk assessments for Phase One and Phase 2a as part of our Environmental Impact Assessment (EIA).

We have engaged with the Department for the Environment, Food & Rural Affairs (Defra) and other transport sector organisations in preparing this report. It uses the road and rail transport framework for adaptation reporting to aid knowledge exchange and learning across the sector.

This report focuses on physical climate risks and adapting to them. Further details of our work on mitigating emissions and delivering low carbon journeys can be found on the HS2 carbon webpage.[17]

17 **hs2.org.uk/why/carbon**

Our governance for climate change

We recognise that climate change poses risks to our strategic goals. Our corporate governance ensures organisational oversight and provides structures and processes to manage risks and realise opportunities related to climate change. Our corporate governance and climate risk management systems are summarised in this section.

2.1 Our governance structure

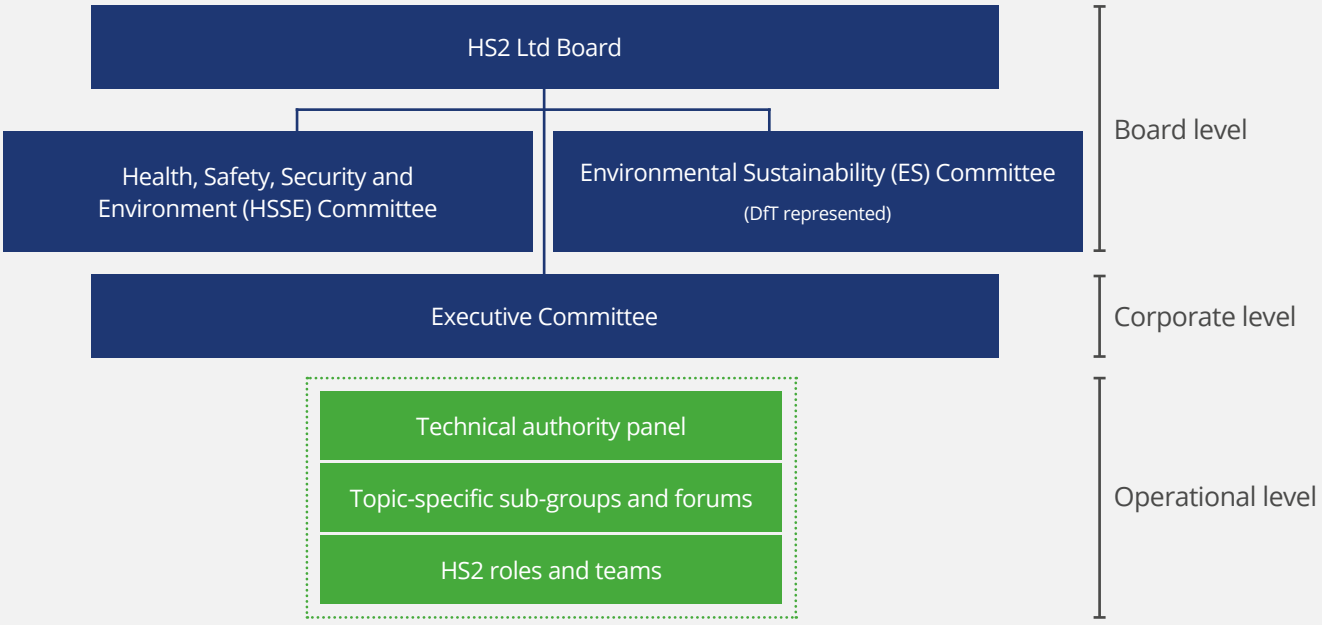
The HS2 Ltd Board provides oversight on environmental sustainability. There are two Board sub-groups for environment: the Health, Safety, Security, and Environment (HSSE) Committee and the Environmental Sustainability Committee (ESC).

The ESC is responsible for strategic direction and scrutiny in support of our environmental sustainability objectives. It has primary oversight of our work on climate change adaptation and resilience.

Membership of the ESC includes non-executive directors and senior executives. We invite external stakeholders to attend committee meetings. In 2021, the chairs of Natural England, Climate Change Committee and the Environment Agency made presentations.

Our climate change team ensures climate change risk, adaptation and resilience is embedded across the business. The team develop guidance for addressing climate change risk in construction, design and operation across all phases of HS2, and raises awareness of climate change across the organisation. Our climate change team presents key developments to the ESC.

HS2 Ltd environmental sustainability governance structure



Our governance for climate change

Our Climate Change Adaptation and Resilience Forum meets regularly and brings together engineers, designers and senior environmental managers to:

- shape the work being undertaken in climate change adaptation and resilience;
- ensure consistency across HS2; and
- act as a forum to provide updates and raise awareness about developments in best practice, key reports and data from the climate change scientific community outside HS2.

2.2 Our organisational risk management processes

2.2.1 Our risk management system

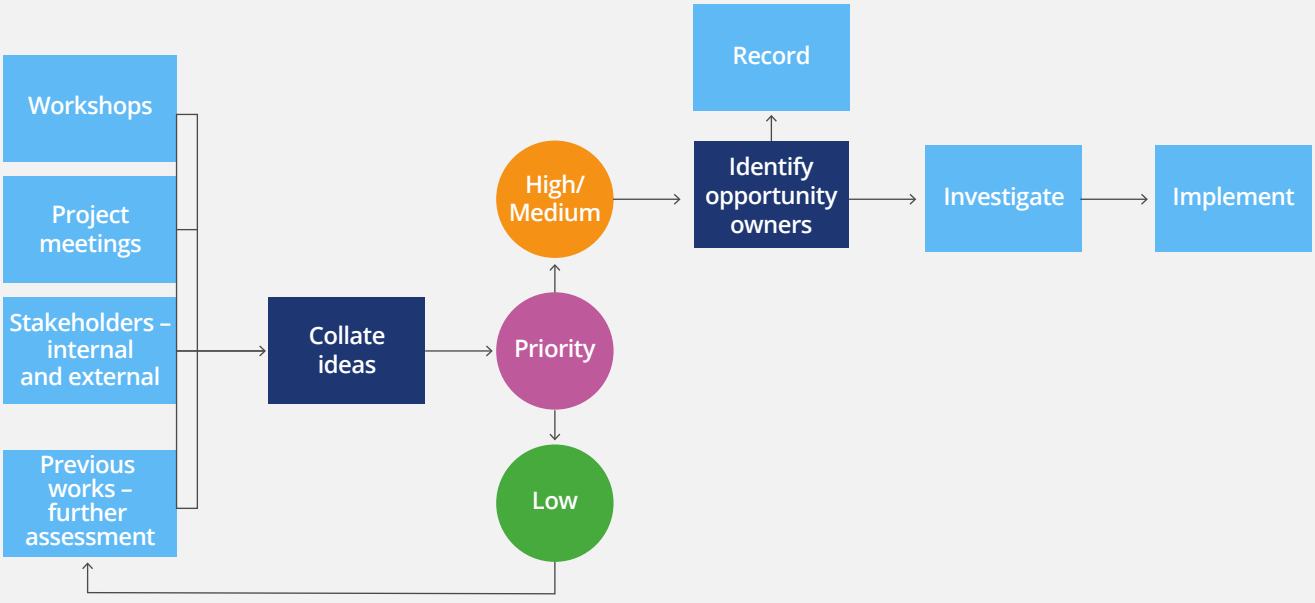
Our enterprise risk management framework aligns with Her Majesty's Treasury Guidance, the Cabinet Office Framework for the Management of Risk in Government and ISO31000:2018 Risk Management.[1] Our Risk Management Strategy and associated procedures provide clarity on the principles, accountabilities, responsibilities and methodology for the effective implementation of risk management in accordance with our Risk Appetite Statement.

All information associated with significant risks, including climate-related risks, is captured in our centralised risk management system. There is an escalation process for significant risks, ensuring that management and the HS2 Board has oversight of principal risks and other specific risks which are assessed as significant.

2.2.2 Our environmental opportunities realisation process

Our environmental opportunities realisation process provides a structured approach through which opportunities, including climate-related opportunities, that may lead to enhanced environmental sustainability outcomes are explored throughout the delivery of the Project (chart below). Through this process, we take a proactive approach to pursuing opportunities that enhance climate change adaptation and resilience for HS2, the environment and communities.

Our approach to identifying and prioritising opportunities



1 **assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1004119/24781_HS2_Annual_Report_2021_web.pdf**

Our adaptation and resilience aims and metrics

3.1 Adaptation and resilience aims

We are committed to delivering a climate resilient rail system and reducing the combined impact of HS2 and climate change on the environment. The table below presents our key climate adaptation and resilience aims.

Our key climate adaptation and resilience themes and aims

Theme	Aim
Climate governance and risk management	Adopt a best-in-class approach to risk management and be a high-performing, innovative organisation, delivering value for money by applying the best design and construction techniques while using exemplar practices in health, safety and security; equality, diversity and inclusion; community relations; and environmental control.[1]
Climate resilience in design and construction	HS2 will be designed to be resilient to impacts arising from weather events and climatic conditions and will be designed in line with HS2 standards, which are built on best practice engineering codes and adapted to consider climate change where appropriate.[2]
Enhancing community climate adaptation and resilience	Maximise benefits to communities and individuals and minimise negative impacts. We will apply the principles in the Sustainability Policy to enhance community climate adaptation and resilience, especially regarding flood resilience and biodiversity.
Ecological resilience and nature-based solutions	• Create a Green Corridor for nature to flourish and for people to enjoy that will conserve and enhance habitats and seek to achieve no net loss in biodiversity in line with the HS2 Environmental Policy.[3] • Our 'green infrastructure' approach will create a landscape that is designed to perform different functions – such as visual screening, flood defence, ecological habitat and noise barrier – and will contribute to increased resilience to climate change.[4] • Maintain a proactive climate change resilience approach for planting trees and vegetation, balancing provenance across the species which are planted.
Climate resilience in operation and maintenance	HS2 will be capable of operating with high levels of train service performance, reliability and resilience including resilience of operations during degraded conditions.[5]

1 **assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1011180/HS2_Annual_Report_2021_Accessible.pdf**
2 **assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/629579/E10_Volume_3_WEB.pdf**
3 **assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/850372/Environmental_Policy__P03__signed_.pdf**
4 **assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/672381/E9_-_Climate_Change_Adaptation_and_Resilience_v1.4.pdf**
5 **assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/916509/hs2-development-agreement-document.pdf**

Our adaptation and resilience aims and metrics

3.2 Adaptation and resilience metrics

In addition to integrating climate change into our standards and risk management system, we monitor the number of climate change adaptation and resilience reports submitted by our designers and contractors (**section 5.2**). This demonstrates that our requirements relating to climate change are being delivered by designers and contractors. This metric is monitored as part of the HS2 benefits programme.

We are developing climate resilience metrics for HS2's construction stage to provide improved tracking of extreme weather impacts. Through our programme, we will continue to develop operational metrics for climate resilience and adaptation. These will be critical for reviewing adaptive capacity and helping to identify thresholds for developing adaptation pathways, an area of ongoing research.

Our climate change risk assessment

4.1 HS2's integrated approach to climate resilience

Identifying, assessing and managing climate change risks is integrated throughout HS2, from the planning and consent process to the assurance of climate resilient design, building the railway and ultimately the maintenance and operation phase.

Unlike many organisations submitting ARP reports and/or considering climate adaptation, our infrastructure is not yet operational. This means we cannot risk assess the performance of our physical assets. We are in the unique position of integrating and embedding climate change adaptation and resilience into the planning, design and construction of a major project (table below).

For the purposes of this adaptation report, we include results based on our risk assessments made during the planning and consent phase for Phase One and Phase 2a and demonstrate our ongoing actions in the design and construction stage. The risk assessments in our Environmental Statements for Phase One[1] and Phase 2a[2] included an assessment of the impact of climate change on infrastructure and assets using the UK climate change projections available at the time – UKCP09 (see timeline on **page 16**). Changes in average climate conditions and extreme weather events were considered in these assessments. Sections on our adaptation and resilience actions, opportunities and ongoing work (**sections 5 – 8**) describe how we use these results in the design and construction stages of the Project.

Integrating climate change adaptation and resilience into the planning, design and construction stages of HS2

Planning and Consent stage	• Climate resilience assessments undertaken for Phase One[1] and Phase 2a[2] as part of HS2 Ltd's EIA process. • Climate resilience assessments applied UKCP09 climate projections for a range of climate hazards over a 120-year time period. • Environmental Statements determine our Environmental Minimum Requirements.[3]
Design Stage	• Integration of climate change requirements within relevant HS2 standards, and periodically updated where required. • HS2 has developed a Climate Change Design Impact Assessment and Climate Change Resilience and Interdependencies Assessment. • Designers and contractors are required to undertake a review of these assessments, providing a Climate Change Adaptation and Resilience Report, including identifying adaptation measures to mitigate any risks.
Construction Stage	• Code of Construction Practice produced for Phase One[4] and Phase 2a.[5] • Designers and contractors are required to monitor and manage the effects of extreme weather events and related conditions during construction.

1 **assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/259614/Volume5_Climate_Change_Resilience_Report_CL-003_000.pdf**
2 **assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/627020/E33_CL-002-000_WEB.pdf**
3 Phase One **assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/593596/Environmental_Memorandum.pdf**
Phase 2a **assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/960226/E176_Phase_2a_EMRs_Environmental_Memorandum.pdf**
4 **assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/593592/Code_of_Construction_Practice.pdf**
5 **assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/960219/Phase_2a_Code_of_Construction_Practice.pdf**

Our climate change risk assessment

4.1.1 Scope of assessment

The climate risk assessment considers the climate change resilience for all HS2 infrastructure and assets to the end of their design life. This means the scope of the assessment varies for each phase and full details can be found in the respective Environmental Statements. The following infrastructure and assets are included in the Phase One and Phase 2a risk assessments.

- Abstraction, drainage and flood conveyance systems.
- Autotransformer feeder stations.
- Earthworks and landscaping.
- Emergency response services (for staff and passengers).
- Feeder stations (National Grid responsibility).
- Fencing and noise barriers.
- Grid supply points (National Grid responsibility).
- HS2 maintenance and accommodation access (i.e. routes facilitating the movement of HS2 staff and landowners).
- Human factors (i.e. the staff and passenger experience of HS2).
- Lineside equipment.
- Mechanical and electrical equipment.
- Overbridges and underbridges.
- Overhead line equipment.
- Rolling stock.
- Signalling and communications.
- Track work.
- Tunnels (including portals and vent shafts).
- Utilities and water supply.
- Viaducts.

The temporal scope of the assessment includes considering risks in both the construction and operation of HS2. We considered climate change risks from the design and construction stages (the 2020s) to the operation stage of HS2 (represented by the last time period available for UKCP09 projections, the 2080s).[6] Where applicable, a mid-century (the 2050s) has also been used to help understanding of climate projections.

Our climate change risk assessment considers weather events and climatic conditions that could potentially worsen or improve due to projected climate change and could affect HS2 infrastructure and assets. Potentially significant climate hazards were identified as part of the EIA process. They are summarised as:

- increased average and extreme temperatures;
- cold conditions and changes in snow conditions;
- increased variations in precipitation patterns and the impacts of flooding and/or droughts; and
- increased frequency of storms including high winds and lightning.

4.1.2 Assumptions and uncertainty

HS2 will be designed to be resilient to impacts arising from weather events and climatic conditions and will be designed in line with HS2 standards. Our standards build on best practice engineering codes and they are adapted, where necessary, to consider climate change.

There is considerable uncertainty in climate modelling, particularly with extreme events. The level of uncertainty is dependent on the climate variable. For example, there is greater confidence about changes in temperature than there is about wind. The projections provided by UKCP09 are 'probabilistic': rather than a single 'best guess' of the impact of climate change, they provide a range of outcomes based on an 'ensemble' of multiple climate model runs. This better represents the uncertainty of climate science.

6 **assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/627020/E33_CL-002-000_WEB.pdf**

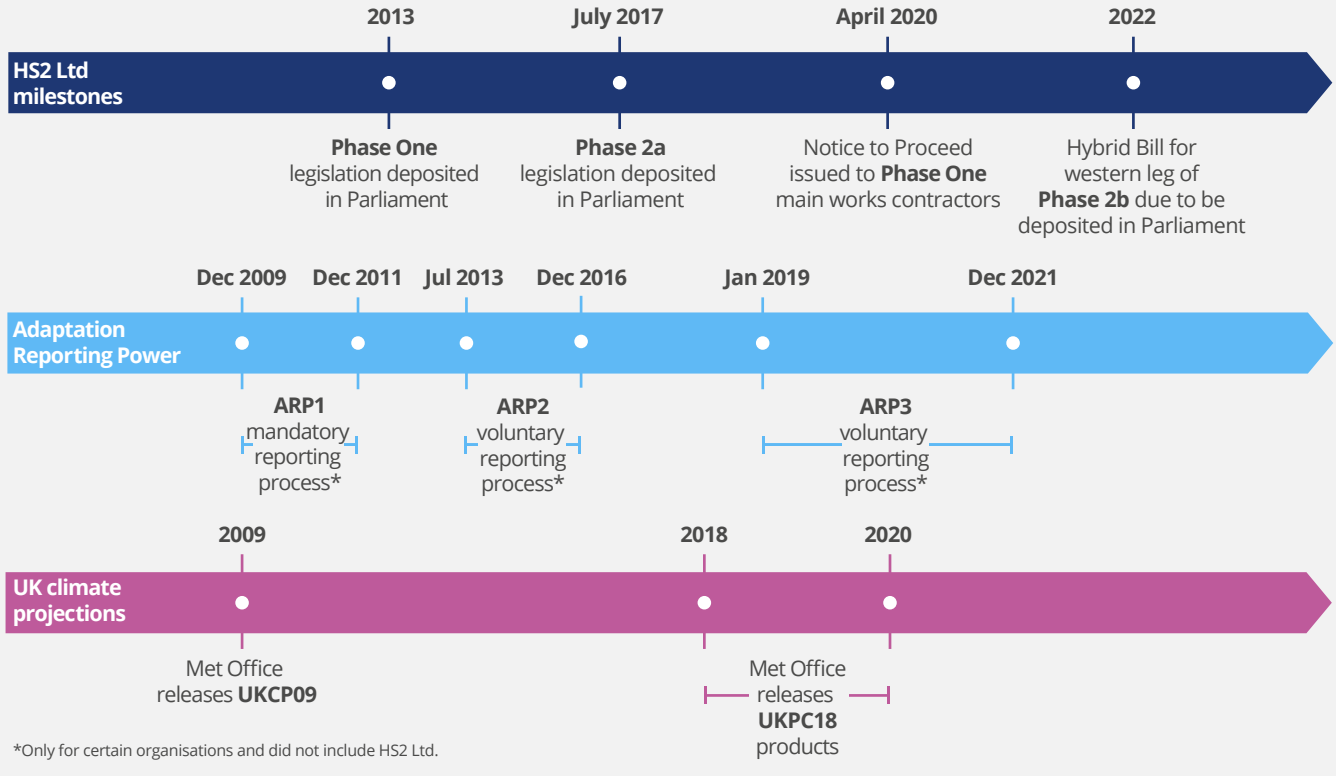
Our climate change risk assessment

There is further uncertainty relating to future climate projections based on socio, economic and political factors. The UKCP09 projections are based on three scenarios of greenhouse gas emissions (low, medium and high) and are provided for seven time periods ('time slices') for the 21st century.

For Phase One, broad descriptions of changes in long-term, seasonal averages and extreme weather events provided by UKCP09 were used to qualitatively assess the impacts of climate change, applying professional expertise and judgment.[7] For Phase 2a, climate change projections for the key climate hazards were obtained for the medium and high emissions scenarios and the 10%, 50% and 90% probability levels from UKCP09.[8]

Understanding of climate science is continuously evolving. Since we deposited our Environmental Statement risk assessments to Parliament, a new suite of climate change projections for the UK (UKCP18) have been released (timeline below). A review of the potential implications arising from the new climate change projections (UKCP18) is underway – see the timeline below.

Timelines showing key milestones related to (from top to bottom) HS2 Ltd, ARP reporting cycles and Met Office UKCP product releases



*Only for certain organisations and did not include HS2 Ltd.

7 assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/259614/Volume5_Climate_Change_Resilience_Report_CL-003_000.pdf

8 assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/629579/E10_Volume_3_WEB.pdf

Our climate change risk assessment

4.2 Risk assessment methodology

The full climate change risk assessment for Phase One can be found **here** and Phase 2a assessment is **here**. This ARP report builds on these (**Appendix A**). Our risk assessment was based on the likelihood of a hazard having an impact on HS2 and the consequence of the impact. The potential likelihood and consequence of impacts to infrastructure and assets were scored using a five-point scale. The Phase One assessment used qualitative definitions for likelihood and consequence. The Phase 2a assessment built on previous work. This included semi-quantitative definitions of likelihood and consequence based on probability levels of the climate hazard occurring. Definitions were based on the likelihood level of an impact to HS2 occurring and consequence criteria for safety, cost, journey times and public perception. These terms are defined as follows.

- **Likelihood** of a hazard is the probability of a hazard occurring and having an impact on HS2, taking into account embedded adaptation and resilience measures to ensure the design is resilient to climate change. Levels of likelihood were defined as 'very likely', 'likely', 'as likely as not/possible', 'unlikely' and 'very unlikely'.
- **Consequence** of the impact refers to the magnitude of the impact on HS2 once the hazard occurs. Levels of consequence were defined as 'very high', 'high', 'medium', 'low' and 'very low'.

Risk is then defined as the likelihood of the impact occurring multiplied by the consequence of the impact of the hazard. The resulting risk level is then assessed and scored as either 'very high', 'high', 'medium', 'low' or 'very low'.

The Environmental Statement assessments considered existing or embedded resilience measures in place or in development for our infrastructure and assets. Learning from Phase One was included in HS2 design and standards, and was used as a basis of the assessment of Phase 2a risks.

Our climate change risk assessment

4.3 Results

Without appropriate mitigation, climate change and severe weather has the potential to affect HS2 in many ways. Some of the potential impacts are shown in the chart below.

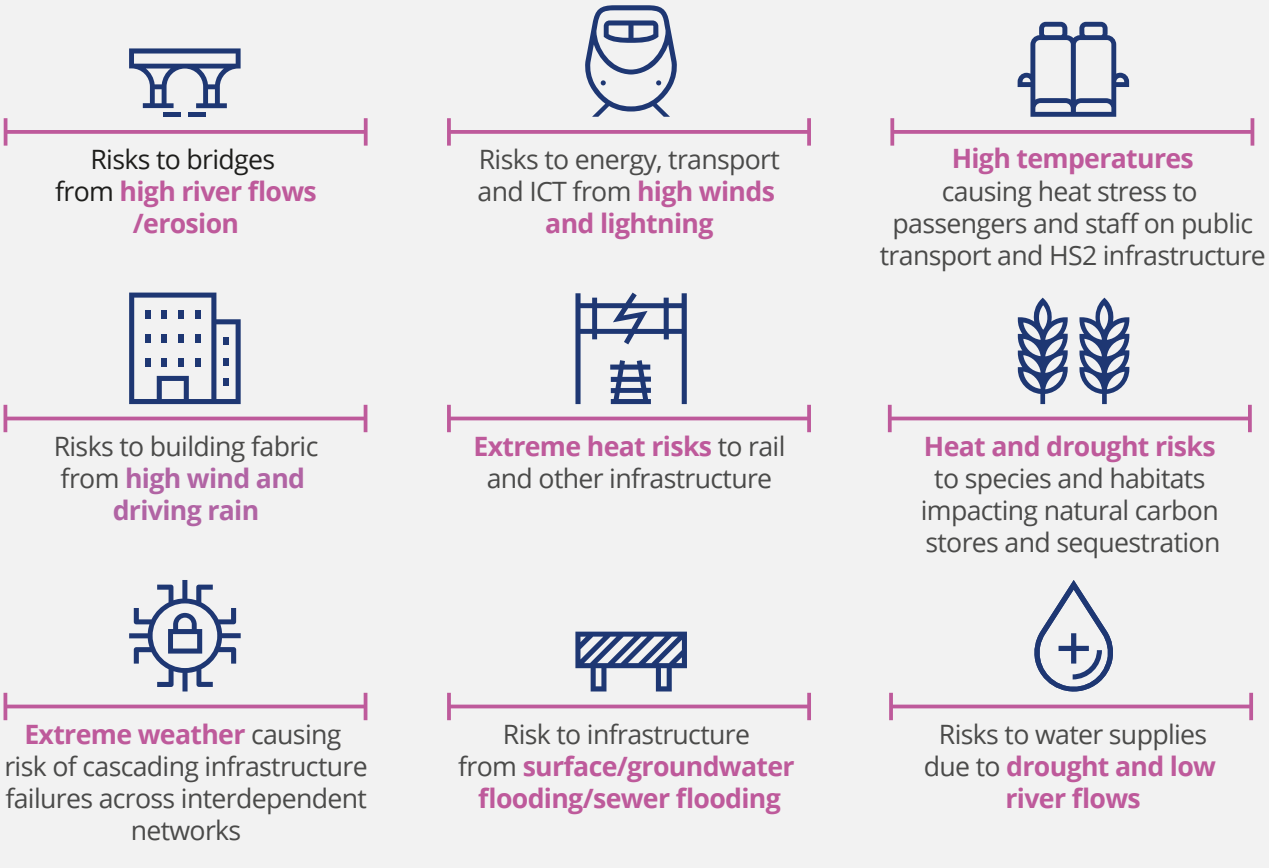
Our Phase One climate change risk assessment identified two high risks: flooding of the track, tunnels and cuttings; and the overheating of tunnels. Adaptation measures have been identified and included in the design stage to mitigate these risks including:

- designing the critical systems infrastructure so it remains operational during a one in 1,000-year (0.1% annual probability of flooding) fluvial flood event, including an appropriate freeboard allowance to prevent track washout; and
- designing drainage to accommodate one in 100-year rainfall events, including an allowance for climate change.

Including these measures in HS2 standards, alongside existing requirements, resulted in no high risks being identified in the Phase 2a assessment. Examples of embedded adaptation and resilience measures are provided in **section 4.3.1.**

To provide climate change adaptation and resilience, HS2 needs to be designed and constructed in line with our standards and guidance, which include our embedded adaptation and resilience measures. We recognise that in some cases operational measures are required to manage climate change risks and ongoing monitoring of adaptation performance is required to ensure we continue to adapt to climate change over time once we are operational.

Potential climate change risks to HS2



Our climate change risk assessment

4.3.1 Examples of embedded adaptation and resilience measures

The risk assessment and the resulting risk scores take account of our embedded adaptation and resilience measures set out in our standards. These standards are periodically reviewed and updated, where needed. Where updates are required, risks are assessed and managed through appropriate channels.

Some examples of potential climate change impacts and risks to HS2 – and embedded adaptation and resilience measures to manage these – are presented in the table below.

Examples of embedded adaptation and resilience measures

Potential climate change impact	Potential risk to HS2	Embedded adaptation and resilience measures for Phase One and Phase 2a
Increased risk of flooding from river, surface and groundwater sources.	Flooding of track.	Our consideration of climate change and flood risk for Phase One initially aligned with the Environment Agency guidance for climate change allowances available at the time of the hybrid Bill design. Guidance has been issued to contractors to consider the 2016 Environment Agency flood risk climate change allowances for all phases and work is ongoing to review the 2021 updates. The HS2 rail line is designed to be resilient to a one in 1,000-year event from all sources and rail levels are set with a freeboard allowance of at least 1 metre above (or otherwise protected from) the one in 1,000-year flood levels to achieve this. Drainage infrastructure is also designed to cope with a one in 100-year + climate change storm event and tested against the one in 1,000-year criteria. This will protect the railway infrastructure from floodwater ensuring the line will remain operational or can restart without undue delay. Additionally, assets that have mammal passes are adequately protected from inundation and have appropriate flow velocity protection. During operation, regular maintenance and monitoring strategies will be undertaken to ensure continual operation of infrastructure.
Increased risk of flooding from river, surface and groundwater sources.	Flooding of access roads and/or road infrastructure linked to HS2, such as access routes for HS2 staff and landowners.	Unless unavoidable, where access is leading to operationally important HS2 assets within the floodplain, access and maintenance routes are designed to be resilient to a one in 100-year + climate change peak river flow event. Drainage infrastructure is designed to cope with a one in 100-year + climate change peak rainfall event (and tested against the one in 1,000-year event criteria if it could potentially flood the HS2 line).

Our climate change risk assessment

Potential climate change impact	Potential risk to HS2	Embedded adaptation and resilience measures for Phase One and Phase 2a
Increased risk of flooding from river, surface and groundwater sources.	Increased risk of scouring of bridge piers and abutments during periods of peak river flow.	Scouring risk is reduced through use of reinforced concrete to strengthen structures of abutments and piers. A residual operational risk may remain as a result of scouring of riverbeds during peak river flow. For new structures in locations exposed to the forces of flowing water, an assessment will be made of the risk of scour. This will consider the risk associated with natural processes (channel migration/degradation), contraction (increases in velocity from channel narrowing) and local (piers and abutments) scour. Assessments will be based on a range of flood return periods up to 200 years, including an allowance for climate change. Protection measures will be designed for the highest flow velocities to increase resilience.
Increased soil moisture levels.	During prolonged wet winters the combination of low soil moisture deficit and rainfall will increase risk of earthworks failure and landslides.	Risk of earthworks failure is mitigated by using robust slope design to allow for future changes in soil moisture content and groundwater pressures as well as using appropriate earthworks materials in embankments. Drainage is designed to a one in 100-year + climate change peak rainfall event. This is coupled with appropriate slope gradient, material (non-shrinkable soil) and/or planting selection (species and location) to ensure earthwork stability as well as continued care of embankments, drainage and (where unavoidable) vegetation management.
Increased number of extremely hot days.	Increased heat stress for staff, particularly for outdoor maintenance workers.	During construction, the Code of Construction Practice requires contractors to consider the impacts of extreme weather events by using a short- to medium-range weather forecasting service to inform programme management. Additional training of personnel and prevention and monitoring arrangements must be provided. Risk of heat stress for staff working indoors during operation is mitigated by buildings being designed to BREEAM (Building Research Establishment Environmental Assessment Method) 'excellent' rating which includes climate change measures. Maintenance workers will need to follow health and safety standards and work is ongoing to prepare appropriate standards for the operational stage. During operations, we will monitor environmental conditions to ensure we are not putting staff at risk during severe conditions where there is a risk of them becoming unwell or being injured.

Our climate change risk assessment

Potential climate change impact	Potential risk to HS2	Embedded adaptation and resilience measures for Phase One and Phase 2a
Increased stress on infrastructure due to extreme winds.	Failure of, or damage to, parts of structures or infrastructure as a result of changes in extreme winds and gusts. Noise barriers and fencing are likely to be most at risk.	Structures are generally deemed not to be sensitive to wind loading as there are no slender/suspension bridge types on HS2. However, auxiliary components such as parapets may be vulnerable to high winds. These will be considered and mitigated through measures to be developed during design stages. Along lengths of HS2 without clearly defined earthworks (e.g. where landscape mitigation earthworks merge into any structural earthworks required), security fencing preferably should be located where gradient of side-slopes are less than one in three. The steeper the slope, the more likely it is that the fence will start to act as a trap for fallen leaves and branches, litter and other debris carried by the wind.
Increased risk of lightning strikes.	Indirect damage to buildings, structures, lineside equipment and cabling traction power distribution sites from lightning strikes damaging trees.	Risk of damage to assets is partially mitigated by trees being planted to ensure they will not fall into the path of a train if they are struck by lightning.
Overall decrease in cold conditions and snowfall, but cold weather events have the potential to be more extreme.	General risk of freezing of mechanical and electrical equipment. Increased risk of rail breaks, ice build-up and drainage systems freezing due to extreme cold.	Risk of mechanical and electrical equipment freezing is mitigated through preventative measures proposed for infrastructure maintenance. Assets will be designed to be resilient to climate change using existing design standards. Maintenance and monitoring measures will also be put in place. Operational restriction, such as speed reductions, will be carried out if sudden and extreme conditions occur.

Our climate change risk assessment

4.4 Coverage of risks from the UK Climate Change Risk Assessment

ARP3 reports are intended to report on the risks identified in the UK's second Climate Change Risk Assessment[9] (CCRA2). Organisations can also report on additional risks and opportunities that they consider to be significant.

Table B-1 in Appendix B presents the risks and opportunities identified in the CCRA2 for rail infrastructure and refers to where these are discussed throughout this adaptation report. These risks and opportunities have also been mapped against the results of our climate change risk assessment. This mapping exercise shows good coverage of the relevant CCRA2 risks and opportunities in our climate change risk assessment, considering the current stage of the Project.

The Climate Change Committee (CCC) recently published its independent report[10] advising the Government on the UK's third Climate Change Risk Assessment (CCRA3), due to be published in 2022. **Table B-2 in Appendix B** shows how the risks for rail infrastructure identified in the CCC's CCRA3 report map across to the risks included in this adaptation report. This demonstrates that our adaptation report has good coverage of the relevant risks from the CCC's CCRA3 report as well as the relevant risks from CCRA2 considering the current stage of the Project.

4.5 Review of implications from UKCP18

In 2018, the Met Office released a new set of climate change projections for the UK (UKCP18), with new and updated products released over the last three years. These are based on the latest versions of the Met Office Hadley Centre climate models and supersede UKCP09 projections.

The Met Office states that the new UKCP18 projections are broadly consistent with the previous UKCP09 projections, showing an increased chance of warmer, wetter winters and hotter, drier summers along with an increase in the frequency and intensity of extreme climatic events.[11] While the UKCP headlines remain largely unchanged, some of the new UKCP products, based on the latest UK Met Office models, highlight risks of much wetter winters and hotter and drier summers, which could have greater impacts than UKCP09 projections suggested.

A review of the potential implications arising from UKCP18 is underway for all phases of HS2, starting with a review of the impacts for Main Works Civils Contracts (MWCC) and stations in Phase One. This includes considering the new projections and updated guidance based on UKCP18 products whilst considering the level of design or construction for infrastructure and assets. The review will identify areas where further work may be required, including potentially updating HS2 standards and accompanying guidance.

9 **assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/584281/uk-climate-change-risk-assess-2017.pdf**

10 **theccc.org.uk/wp-content/uploads/2021/07/Independent-Assessment-of-UK-Climate-Risk-Advice-to-Govt-for-CCRA3-CCC.pdf**

11 **metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/research/ukcp/ukcp-headline-findings-v2.pdf**

Our work on climate adaptation and resilience

This section outlines the existing and proposed adaptation and resilience actions we have in place at each stage of the Project to ensure that climate hazards and their impacts are carefully considered and managed.

The development of standards and impact assessments within our planning and consent and design stages ensures that climate adaptation and resilience are integral to the construction and operational stages of HS2.

5.1 Climate adaptation and resilience in the planning and consent stage

For HS2, climate adaptation and resilience starts at the project outset. We include climate change assessments as part of our planning and consent stage. We carry out a high-level climate change resilience assessment for each phase of the railway, in our Environmental Impact Assessments (EIAs). This is to identify the range of potential risks and to assess the railway's resilience and capacity to cope. These assessments consider the risks posed by extreme hot and cold weather, heavy rain, high winds and storms to railway infrastructure including tracks, tunnels, overhead line equipment, rolling stock, stations and earthworks.

An in-combination climate change assessment is also completed, which considers how climate change, in combination with the impacts of the Project, may affect communities, businesses and the natural, historic and built environments.

Case study

Climate change resilience Environmental Impact Assessments for Phase One and sharing best practice

HS2 Phase One was one of the first projects of HS2's size to include climate change adaptation and resilience assessments into its EIA. Our assessments have been cited as examples of good practice by the Climate Change Committee.

It said: "The comprehensive approach taken by HS2 Environment Statement (for Phase One) to the full range of climate risks serves as an example of good practice."[1]

We have collaborated with others to develop leading standards on climate change assessment and management. For example, we worked with the Institute of Environmental Management and Assessment (IEMA) on its recent guide on the effective consideration of climate change resilience and adaptation in the EIA process, providing a case study for this best practice guidance.[2]

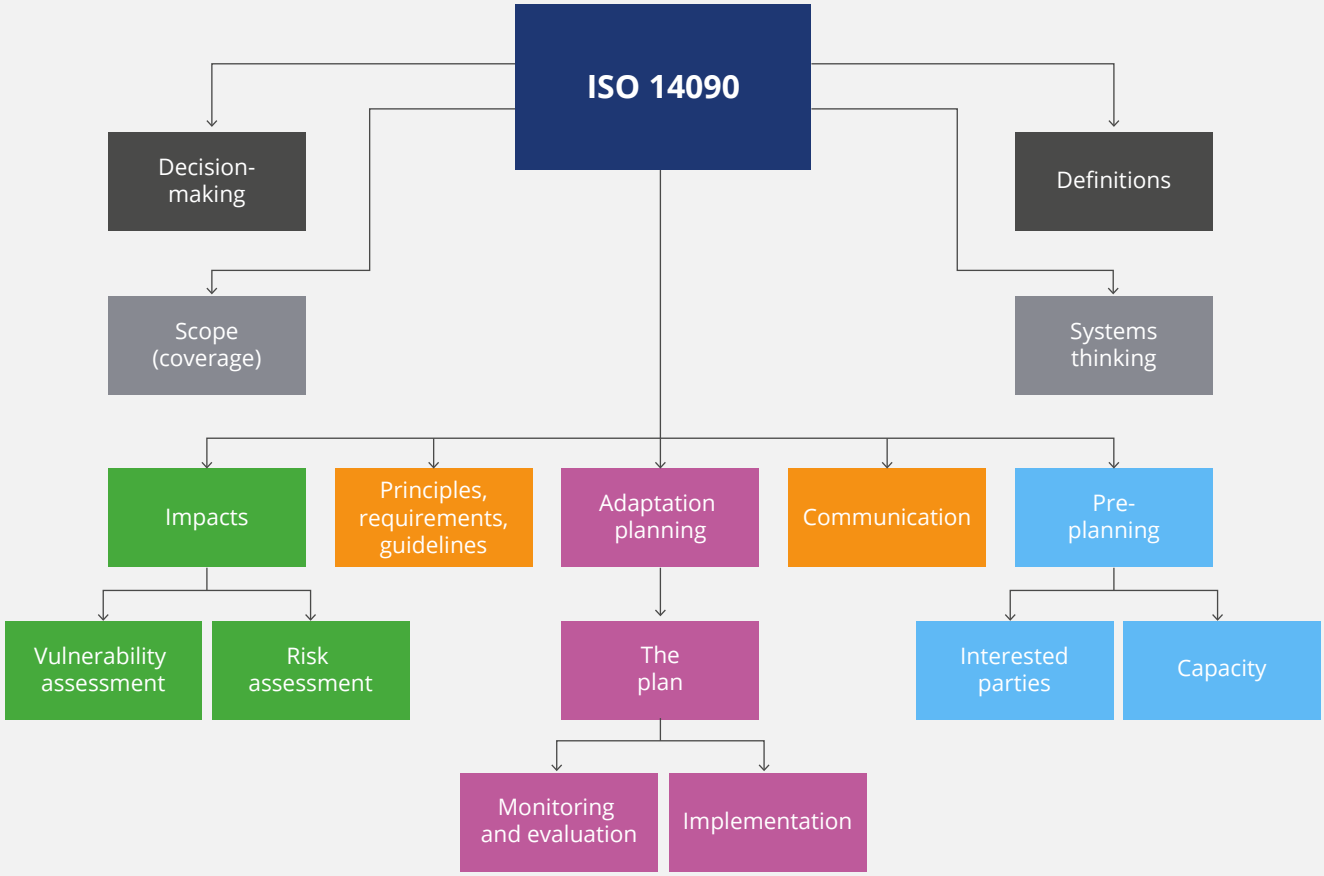
We have also worked with British Standards Institution as a stakeholder on the ISO 14090 adaptation to climate change standard. This standard offers a framework that enables organisations to give appropriate consideration to climate change adaptation when designing and carrying out policies, strategies, plans and activities (see diagram on **page 24**). We also sit on BSI's greenhouse gas and adaptation sub-committee.

1 **theccc.org.uk/wp-content/uploads/2014/07/Final_ASC-2014_web-version.pdf**

2 **iema.net/resources/reading-room/2020/06/26/iema-eia-guide-to-climate-change-resilience-and-adaptation-2020**

Our work on climate adaptation and resilience

Key themes of ISO 14090[3]



5.2 Climate adaptation and resilience in the design stage

5.2.1 Climate change standard

HS2 is designed in line with our standards, which are built on best practice engineering codes and adapted to consider climate change where appropriate. Our standard for climate change adaptation and resilience outlines requirements contractors must follow to ensure adaptation to climate change risk. The requirements ensure assets are resilient and their reliability remains satisfactory throughout their design life. It encourages consideration of reliability, redundancy and response and recovery in the design of infrastructure.

To ensure that climate change risks are considered and managed in all stages of design, the climate standard is based on our climate assessments.

- We developed a bespoke process for ensuring climate change is considered in the design of HS2. The Climate Change Design Impact Assessment (CCDIA) assesses the suitability of our standards to future climate change and identifies where additional allowances may be required to ensure climate resilience. To date, a CCDIA has been developed for Phase One main works and stations, and work is ongoing to develop a CCDIA for rail systems which will apply across Phase One and 2a.

3 Adapted from: **bsigroup.com/en-GB/blog/Environmental-Blog/bs-en-iso-14090/**

Our work on climate adaptation and resilience

- We have developed a bespoke process for our designers and contractors to assess the impact of climate change on the interdependent infrastructure in their designs (see **section 6** for more information). Our Climate Change Resilience and Interdependencies Assessment (CCRIA) categorises, assesses and priorities risks arising from climate change impacts on HS2's interdependent infrastructure. The outcomes of the CCRIA provide the evidence to support design decisions that are proportionate to the impacts and risks identified or they identify if further work is required. To date, a CCRIA has been developed for Phase One.

Our climate standard requires our contractors to review our design impact and interdependencies assessments at the key design stages. Changes to design for climate change resilience can then be included and agreed. The contractors report their review in a Climate Change Adaptation and Resilience Report (CCARR) which must demonstrate that the design, as far as reasonably practicable, maximises resilience to climate change, maximises the potential for adaptation to climate change in the future and minimises the risk of loss of performance due to the impacts of climate change on interdependencies. Designers and contractors are required to identify and record the impacts (e.g. cost, carbon emissions and other benefits or disadvantages) associated with any proposed climate change resilience design improvements. The reports are assured by HS2 Ltd and risks are recorded in our risk management system, with the intention to manage these during the design stage (**section 2.2**).

Case study

Contractors review of the CCDIA and their actions

Our contractors' Climate Change Adaptation and Resilience Reports provide their response to HS2 recommendations made in the CCDIA. The CCDIA assess the resilience of standards and/or designs to future climate change to inform their development. The CCDIA defined the relevant HS2 asset types and their expected design lives, then used UK climate projections and qualitative assessment to determine the potential impacts of climate change on the design and performance of the system.

The contractors are required to review the CCDIA for the specific assets of their contract and report this in their Climate Change Adaptation and Resilience Report. The outcomes of this review provide the evidence to support design decisions that are proportionate to the impacts and risks identified, or identify if further work is required.

At an asset level, the CCARR describes where climate risks are addressed through HS2 standards, where design changes are required, where redundancy (i.e. the availability of backups or spare capacity) has been included in the design or where the issue should be included in a watching brief.

Additionally, contractors have identified where techniques such as adaptive management should be promoted in the detailed design stage following the CCDIA review. For example, overbridges have been designed to allow future adaptation to climate change as more data and information on the occurrence and strength of winds in the future becomes available. Contractors have also noted where assets and climate change impacts should be included in a watching brief to identify decision thresholds.

Our work on climate adaptation and resilience

5.2.2 Other standards

We also set out requirements for climate change adaptation in other asset-specific and topic-specific standards and guidance, such as flood risk, landscape design and ecological resilience.

Standards are developed, approved and reviewed following our governance and risk management processes (**section 2**). They will be periodically reviewed and updated.

Case study

Climate resilient design for earthworks stability

Soil moisture and groundwater levels can vary substantially in response to meteorological and seasonal trends, which will be exacerbated by climate change. UKCP18 local data suggests a future increase in the intensity of convective heavy summer rainfall events, despite overall summer drying trends in the future.[4]

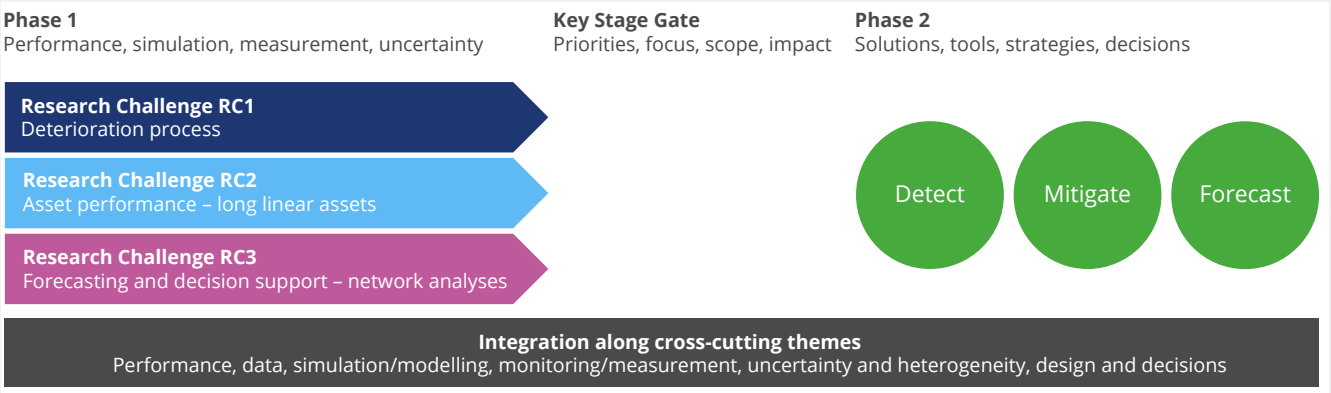
The length of earthworks in Phase One consists of 60km of embankment and 74km of cutting. For Phase 2a, there are 36 embankments and 26 cuttings in total. Their stability will be critical for HS2 operations.

The climate impact of the combination of these climate variables is difficult to quantify. This means our earthwork designers adopt a cautious design approach. They use the worst credible groundwater conditions and characteristic strength values in design, considering climatic and seasonal variations (including allowances for climate change) to manage this uncertainty.

Our standards also consider lineside vegetation. This ensures that any existing or newly planted vegetation with high-water demand on highly shrinkable soils is a satisfactory distance from the nearest rail.

In addition, our head of geotechnics is a member of the Achilles Impact Advisory Group. Achilles[5] is grant funded by the Engineering and Physical Sciences Research Council and focuses on the geotechnical aspects of long, linear assets such as railway embankments and cuttings to both better understand the climate risks to earthworks and to evaluate the impact of design decisions on the resilience of earthworks to a changing climate. The graphic below presents an outline of the research challenges and research phases. We consider any research outcomes and, if necessary, any updates to our standard will be made considering new research.

An outline of the challenges and research phases of the Achilles programme grant[6]



4 **metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/research/ukcp/ukcp-headline-findings-v2.pdf**

5 **achilles-grant.org.uk**

6 Adapted from: **achilles-grant.org.uk/programme/the-research-challenge**

Our work on climate adaptation and resilience

Case study

Climate resilient in HS2's Green Corridor

Climate change resilience extends beyond the infrastructure of HS2. When the Project affects the environment, it is important that resilience is also considered. For this reason we are integrating resilience into HS2's Green Corridor.

The Green Corridor is the largest, single environmental project in the UK.[7] More than 33 square kilometres of new woodland, wildlife and river habitats are being created along the Phase One route between the West Midlands and London, the equivalent of 23 new Hyde Parks.[7]

Integrating resilience into our Green Corridor will ensure climate change is considered in decisions about landscape design. This approach helps us to ensure the environment surrounding the railway is also managed with climate adaptation and resilience in mind.[7]

Part of the Green Corridor's legacy will be its contribution to a range of national environmental strategies and schemes. For example, we would like to explore how we can embed the emerging National Framework of Green Infrastructure Principles into the Green Corridor.[7] These principles call for action to address challenges including coping with the impacts of climate change. Such action is necessary for building more resilient and prosperous communities.

Following advice from Natural England and the Forestry Commission, Phase One's planting strategy states that a third of all planting stock should be from the same UK regional provenance as the planting site, a third from up to 2° latitude south of the planting site and a third from 2° to 5° latitude of the planting site. This approach increases resilience to climate change.

The Colne Valley western slopes project will transform an HS2 construction site into one of the largest areas of new chalk grassland in the Chiltern Hills.[8]

The design includes creating 127 hectares of species-rich calcareous grassland, wood pasture and wetland habitat across an area dominated by arable fields. This will constitute the largest area of calcareous grassland in the Chilterns and will be one of the single largest contributors to biodiversity improvement in the Colne Valley.

Planting new trees, creating new habitats for wildlife and building green infrastructure will help people and wildlife adapt to climate change by capturing and storing carbon, reducing temperatures, improving air quality, reducing flooding and helping wildlife to move around more freely. It will also help improve rivers and other aquatic environments and improve water quality.

Above is an architect's impression of the Chilterns chalk grassland project – the Colne Valley western slopes grassland project.[8]

7 **assets.hs2.org.uk/wp-content/uploads/2020/12/11152821/24136_HS2_GreenCorridor_v43_CS1469_Interactive.pdf**

8 **hs2.org.uk/in-your-area/local-community-webpages/hs2-in-hertfordshire/colne-valley-western-slopes**

Our work on climate adaptation and resilience

5.2.3 Sustainability assessments

We are committed to using recognised environmental sustainability ratings BREEAM[9] and CEEQUAL[10] for assessing the design and construction of all our stations, depots, control centre and infrastructure works.[11]

BREEAM sets the standard for best practice in sustainable design. BREEAM credits can be made up of several themes including items relating to climate change adaptation and resilience. As part of our work on BREEAM, we have set requirements to ensure that our designers and contractors obtain the credits for climate change adaptation and resilience for our stations.

We see these stations not just as construction projects, but as opportunities to create transformational green infrastructure.[12] The stations and their surroundings will include green buildings and new public spaces, including open spaces and landscaping. These will feature parkland lawns, rain gardens to capture water, wildflower grassland, new trees and an area of new woodland to provide a natural habitat for wildlife. Initiatives like these can help cool the urban environment and reduce our own water use[13] and provide co-benefits with carbon mitigation and biodiversity.

Case study

Managing heat at Old Oak Common station

Adaptation measures are being developed to manage the effects of high temperatures in the proposed design for Old Oak Common station, which will conform to HS2's standards for station platform temperatures. The design features exposed surfaces that will absorb solar radiation entering through the rooflights and other unshaded areas to minimise the risk of indoor air temperature increases. We will also include 'shading devices' to minimise the risk of overheating in both indoor and outdoor spaces.

Key access routes and seating spaces at Old Oak Common will include tree canopy cover. The surfaces of footpaths and cycle paths will use reflective materials to minimise the amount of solar radiation that is absorbed. Some hardstanding areas will also be partially permeable to help cool the pavement through evaporation of water.

Mechanical ventilation systems will ensure internal temperatures remain low to prevent overheating of equipment and subsequent loss of service.

9 Building Research Establishment Environmental Assessment Method: **breeam.com**

10 Civil Engineering Environmental Quality Assessment and Award Scheme: **ceequal.com**

11 **assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/902492/_HC_399__-_Report_and_Accounts_of_High_Speed_Two__HS2__Limited.pdf**

12 **assets.hs2.org.uk/wp-content/uploads/2020/12/11152821/24136_HS2_GreenCorridor_v43_CS1469_Interactive.pdf**

13 **assets.hs2.org.uk/wp-content/uploads/2020/08/27141256/24260_HS2-Corporate-Plan-2020.pdf**

Our work on climate adaptation and resilience

Case study

The world's first station for outstanding sustainability

Interchange station in Solihull has been awarded BREEAM outstanding certification for sustainable buildings – a first for any railway station in the world, putting it in the top 1% of eco-friendly buildings in the UK.[14]

The award recognises Interchange's green features, including the station roof design which can capture and reuse rainwater to reduce the mains water demand for the station. The estimated volume of the rainwater harvesting tank is 150 cubic metres.[15] This increases HS2's resilience to drought and extreme heat.

Landscaping features include sustainable drainage systems to reduce the burden on surface water drainage during periods of intense rainfall while naturally irrigating planted areas.

5.3 Climate adaptation and resilience in the construction stage

The impacts of climate change on temporary and permanent construction activities and assets are assessed as part of our EIA process. The combined impact of climate change and HS2 activities on the environment is also considered during the construction period.

To protect the railway infrastructure while it is being built, our Code of Construction Practice (CoCP) for Phase One[16] and Phase 2a[17] have requirements that reduce risks relating to extreme weather and associated conditions.

The CoCP for Phase One and 2a requires the contractor to carry out the following measures to increase climate resilience.

- Use short- to medium-range weather forecasting services from the Met Office or another approved meteorological data and weather forecast provider to inform medium-term programme management, environmental control and impact mitigation measures.
- In areas at flood risk, contractors are required to register with the Environment Agency's Floodline Warnings Direct service and develop flood mitigation proposals to mitigate the impacts of HS2 and reduce flood risk to communities, where reasonably practicable.
- Carry out additional measures, as appropriate, to ensure the resilience of the proposed mitigation of impacts during extreme weather events. This should cover training of personnel and prevention and monitoring arrangements.

14 **assets.hs2.org.uk/wp-content/uploads/2020/08/27141256/24260_HS2-Corporate-Plan-2020.pdf**
15 **hs2.org.uk/building-hs2/sustainability-and-environment/building-a-climate-resilient-high-speed-railway/**
16 **assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/593592/Code_of_Construction_Practice.pdf**
17 **assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/960219/Phase_2a_Code_of_Construction_Practice.pdf**

Our work on climate adaptation and resilience

During construction, we are also managing in-combination climate change impacts. We know that climate change will impact the availability and quality of water resources, so we are managing and conserving water to reduce our demand.[18] This reduces stress on the public water network, ensures more water is left in the environment and helps to improve resilience of the water supply.

Our interaction with the water environment is regulated by the Environment Agency in line with the existing stringent regulations. We are also working closely with all water undertakers along the route such as Thames Water and Affinity Water to ensure that the supply of construction water is sustainable.

Case study

Balfour Beatty VINCI and Align

Our partners building HS2 are responsible for minimising and compensating for the impact of their construction work on people and the environment. Our partners are working closely with us to deliver commitments made and agreed in Local Environment Management Plans (LEMPs), which have been produced with each affected council area along the HS2 route.

Balfour Beatty VINCI's (BBV) green tunnel initiative near the village of Kenilworth, Warwickshire, will help the rewilding and enhancement of the natural habitat. The green roof of the tunnel will also serve to improve water infiltration around the railway offering improved flood resilience.

When the work is completed, our contractor will seek to enhance biodiversity by replacing lost habitats and planting new native species of trees.[19] In this way we will preserve natural capital in this area and increase the site's resilience to climate change.

Case study

Construction in the Chilterns

HS2 will not place any additional burden on the chalk aquifer in the Chilterns. We have introduced water efficient tunnel-boring technology and spent over £100 million enhancing water treatment capacity in the region to ensure that high quality, potable water can continue to be supplied.

The tunnel boring machines (image above) are specifically designed to protect groundwater and be as clean as possible. They use water to carry away excavated material as a slurry.

We are also innovating in water management. Worksop-based Wright Engineering has built a closed loop water treatment plant to recycle and reuse water at the tunnel's south portal site, where about two-thirds of water demand will come from the plant.

Through these measures, we are protecting our construction programme from potential impacts of drought and reducing greenhouse gas emissions.

18 **hs2.org.uk/in-your-area/managing-impacts-of-construction/water-supply-and-management/**

19 **assets.hs2.org.uk/wp-content/uploads/2020/08/27141256/24260_HS2-Corporate-Plan-2020.pdf**

Our work on climate adaptation and resilience

5.4 Climate adaptation and resilience ahead of the operation stage

We started planning and collaborating on climate resilience before we started building HS2. Our climate resilient design and our operational planning will ensure we can operate at a high level of resilience, including during potential disruption from extreme weather and climate hazards.

We are developing a rigorous safety management system for the operation of the network to record adverse events and take appropriate action. This work is ongoing ahead of our projected start of operations in the range 2029 to 2033 for Phase One. We will undertake the necessary maintenance and monitoring of conditions during operation to minimise disruption and ensure we can continue to be adaptive to climate change over time.

HS2 will also operate on existing and planned rail infrastructure built and maintained by different providers. We are taking a proactive approach to work with other rail providers to increase climate resiliency as part of our work on interdependencies (**section 6**). We are working with industry and academic partners to develop a better understanding of climate change adaptation and resilience for the benefit of HS2 and other major projects.

Case study

Working with industry peers to manage environmental risks

We were involved in a cutting-edge research programme[20] – the Environmental Risks to Infrastructure Innovation Programme – led by the Natural Environment Research Council. One of its aims was to translate existing research into tangible, industry-relevant tools and approaches that help infrastructure owners manage environmental risks.

We have also contributed to Tomorrow's Railway and Climate Change Adaptation[21] – a research project run by the Rail Safety Standards Board. The project has provided a range of decision-making tools and information to allow railways to become more resilient. The tools include methods for financially evaluating climate adaptation investments, geospatial-based methods to integrate many of the metrics captured by the industry and systems tools to provide insight into critical interfaces and dependencies, inside and outside of the railway system.

We are part of the Infrastructure Operators Adaptation Forum which includes representatives from all other major infrastructure sectors including Network Rail, National Grid and water companies. Forum members share knowledge, learn from each other and work towards a vision for infrastructure assets and services that are resilient to today's natural hazards and prepared for the future climate. We belong to other stakeholder groups such as Rail Safety Standards Board's Climate Change Adaptation Working Group and the Transport Adaptation Working Group.

20 **nerc.ukri.org/innovation/activities/infrastructure/envrisks/**
21 **sparkrail.org/Lists/Records/DispForm.aspx?ID=3745**

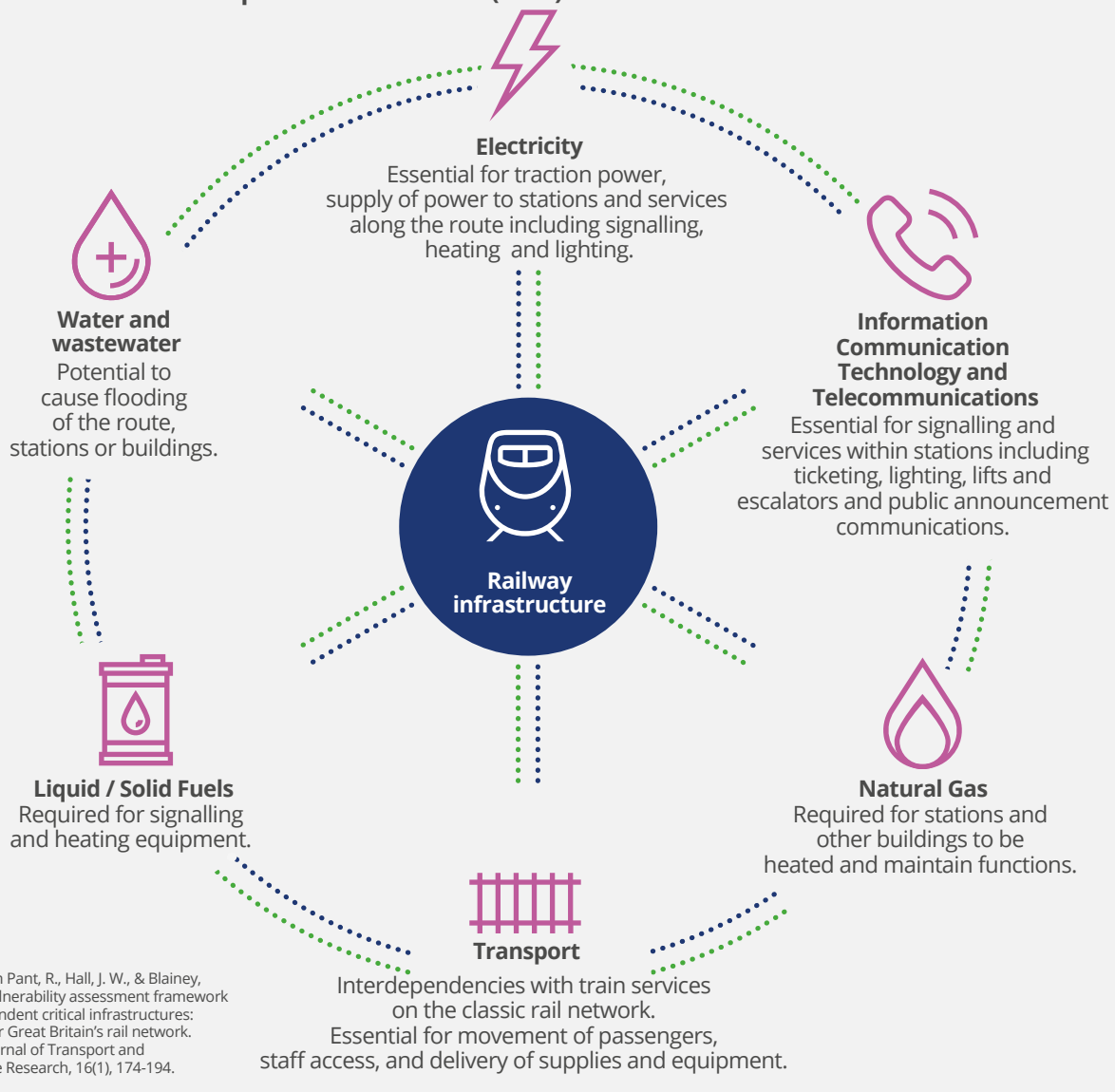
Our interdependencies

6.1 Managing our interdependencies

We recognise that adaptation and resilience cannot be delivered alone. The interconnected and interdependent nature of the UK transport sector and our asset systems means there are risks to our services from impacts felt from external organisations, assets and services that we interface with or rely on. For example, we have interdependencies with the power network, points where our system connects to Network Rail's system and where our assets interact with each other, such as drainage and earthworks. A climate change impact could have a cascading impact across our assets and the wider network through external companies. We have embedded the need for our designers and contractors to understand our systems, their interdependencies and the risks that our systems face.

To do this, we undertook a Climate Change Resilience and Interdependencies Assessment (CCRIA) to identify our interdependent infrastructure, namely: energy; information and communications technology; water; waste management, and other transport systems. A schematic of the primary interdependencies for rail infrastructure is shown in the chart below.

Simplified interdependencies mapping between key infrastructures for HS2 based on our CCRIA and adapted from Pant et al (2016)*



*Adapted from Pant, R., Hall, J. W., & Blainey, S. P. 2016. Vulnerability assessment framework for interdependent critical infrastructures: case-study for Great Britain's rail network. European Journal of Transport and Infrastructure Research, 16(1), 174-194.

Our interdependencies

We require all our designers and contractors to review the CCRIA and consider where their designs may be vulnerable to the impacts of climate change from interdependent systems, services or assets. This is reported to us in a Climate Change Adaptation and Resilience Report (CCARR). Risks and opportunities are recorded on our central risk management system to ensure that they are managed throughout design. Where necessary, designers and contractors are required to propose design solutions to improve resilience to these interdependencies.

We will be setting up a collaboration group for climate resilience with our contractors and will use this as an opportunity to discuss interdependencies and cascading impacts across our network. This will support better mapping and understanding of potential impacts with relation to climate change. This work will also be supported by our involvement in industry peer collaboration groups such as the Infrastructure Operators Adaptation Forum.

Case study

Contractors review of the CCRIA and their actions

The Climate Change Adaptation and Resilience Reports provided by our contractors explain their response to HS2 recommendations made in the Climate Change Resilience and Interdependencies Assessment (CCRIA). This includes considering how to apply the recommendation to the contract, how the recommendation will be carried out or the reason why it is not appropriate for action at this stage of the contract design. Key recommendations considered by contractors include the following.

- Where and how 'redundancy' (that is, the availability of backup or spare capacity) can be built into the system to cater for external failures due to climate hazards and future climate change.
- Building in redundancy and resilience on a system-wide basis through collaborative work with local infrastructure operators.
- Examine 'what if' scenarios to consider mitigation actions for coping with failure of other assets.
- Identifying geographical interdependencies where assets cross the route or are integrated with the route.

Contractors have noted third parties who are critical for discussions on interdependency. These include transport companies, local planning authorities, utilities companies, communication companies and other HS2 contractors.

Contractors have also evolved their designs to increase redundancy and resilience. This includes providing redundancy in drainage designs, twinning of third-party utilities such as water mains and inclusion of spare ducts in electricity cables for future capacity increases. Contractors have also designed multiple systems with the same function for resilience including spare pumps for water and drainage pumping and connections to multiple grid substations.

Contractors will continue to submit CCARR as their design progresses which will include considering interdependencies and updated actions. Discussions with key third parties are ongoing and will inform the climate adaptation collaboration group we will establish.

Our climate adaption challenges and opportunities

We have faced challenges with integrating climate change into the Project but we've also seized opportunities to improve climate resilience and provide wider benefits beyond HS2.

Other construction projects and infrastructure operators may face similar challenges and opportunities and we are sharing what we have discovered to increase awareness and inform wider policy and planning.

7.1 Our challenges

- Many international design standards and guidelines are several years old and are based on historic weather data without allowances for climate change. HS2 standards are built on best practice engineering codes and adapted to consider climate change where appropriate.
- International design standards and guidelines are periodically updated and information on climate change is constantly evolving. This causes challenges for projects like HS2 with multiple stages of design and construction. In some cases, we have had to assess the implications of changes to climate data, standards and guidelines to work out whether additional allowances or modifications need to be made in the design. For example, we are reviewing the potential implications of the UKCP18 climate projections on Phase One and Phase 2a designs.
- There is still no best practice approach to projecting climate change. There is no specific guidance on which climate change scenarios organisations should use to prepare for climate change. We address this by considering a range of climate change scenarios in our environmental assessments and design, and we use sensitivity testing where applicable.
- There is uncertainty and information gaps relating to some climate variables, making it difficult to design and construct assets with very long lifetimes. For example, data related to how climate change may impact windspeeds, fog and snow is limited. Our standards will be periodically updated, where required, with new scientific information and climate projections. If needed, we will commission further research.
- Managing climate change risks related to interdependencies is challenging because interdependent infrastructure is generally older and is unlikely to have the same level of resilience. We also have limited influence to enhance the resilience of other systems. While we have developed an approach to managing climate change risks arising from interdependencies, other infrastructure operators may be limited in their ability to enhance their own resilience, collaborate and share information on vulnerabilities and thresholds. We are working across industry groups to share best practice and collaborate on interdependency issues to improve understanding and encourage greater resilience.

Our climate adaption challenges and opportunities

7.2 Our opportunities

- Designing and building new infrastructure or enhancing existing infrastructure is an opportunity to embed climate resilience. We've taken the opportunity to embed climate adaptation and resilience into our standards, our systems and our governance. We aim to set a good example for other projects and infrastructure operators.
- We're helping to build capacity on climate change adaptation and resilience throughout our supply chain. We are doing this through our procurement processes and requirements on designers and contractors in our HS2 standards.
- Climate resilience knowledge developed through programmes like HS2 can benefit other projects. We're pleased that some of the knowledge and best practice developed through HS2 can benefit future projects and other existing infrastructure operators. We've taken the opportunity to share knowledge, for example, through our Learning Legacy papers.
- Projects like HS2 have the opportunity to deliver wider adaptation and resilience benefits to communities and the environment. We're creating wider benefits which will help the UK to meet its climate change adaptation goals, as well as many goals under the 25 Year Environment Plan. We're working to ensure the benefits of HS2 are achieved and shared across the UK.
- Engaging with the Adaptation Reporting Power (ARP) process during the project stage can help to embed climate change adaptation and resilience into infrastructure from the outset. Producing our first ARP report has benefited our organisation in highlighting progress, identifying ongoing actions and fostering engagement and support for adaptation and resilience across the Project. We hope to set an example of good practice in submitting our report. We are committed to sharing widely how we are embedding climate change adaptation and resilience into HS2 from the outset and the lessons we are learning along the way.

Conclusion

8.1 Our ongoing work

We are integrating climate change adaptation and resilience into each stage of the Project and our work in this area is central to our company polices and strategic goals. Our infrastructure is being designed to withstand the impact of climate change and extreme weather, and we are putting mitigations in place to limit our impact on communities and the environment.

We are also taking opportunities to deliver additional value, such as by creating habitats, enhancing flood resilience for communities and carrying out nature-based solutions. Our work to deliver on climate adaptation and resilience is ongoing. Our journey is presented in the table below and we will use this to measure progress in future reporting rounds.

#	Action	Project stage	Status
1	Ensure climate risks are managed throughout the Project with appropriate governance and risk management.	**All**	**Ongoing**
2	Assess the impact of climate change on future phases of HS2 and consider the resilience of all phases to climate change.	**Planning and consent**	**Planned**
		Design	**Planned**
3	Review and update HS2 standards and supporting documents as climate change evidence and data evolves and develop new standards where appropriate.	**Design**	**Ongoing**
4	Undertake climate change design impact assessments and interdependencies assessments as necessary.	**Design**	**Ongoing**
5	Ensure designers and contractors develop and submit Climate Change Adaptation and Resilience Reports for Phase One and Phase 2a.	**Design**	**Ongoing**
6	Establish a climate change resilience collaboration group with contractors.	**Construction**	**Planned**
7	Ensure the impacts of climate change on construction are assessed and monitored, meeting the requirements in our Code of Construction Practice.	**Construction**	**Ongoing**
8	Develop metrics for climate adaptation and resilience for the construction and operation phases.	**Construction**	**Ongoing**
		Operation	**Planned**
9	Develop adaptation pathways, where applicable, including monitoring requirements.	**Design**	**Planned**
		Operation	**Planned**

Conclusion

#	Action	Project stage	Status
10	Undertake operational planning to ensure we are ready for resilient operation and ready to manage risks from climate change, such as extreme weather. This includes the ability to monitor performance during operation to provide insight and allow us to adapt to climate change.	**Operation**	**Ongoing**
11	Work with our partners, supply chain and stakeholders to achieve our climate change adaptation and resilience objectives including managing interdependent climate risks.	**All**	**Ongoing**
12	Engage in industry and academic partnerships to develop our understanding of climate change adaptation and resilience. Seek opportunities to innovate and share knowledge.	**All**	**Ongoing**
13	Host regular meetings of the HS2 Climate Change Adaptation and Resilience Forum, bringing together engineers, designers and senior environmental managers.	**All**	**Ongoing**
14	Provide updates on our adaptation progress and new phases of HS2 in future Adaptation Reporting Power reports.	**All**	**Ongoing**

Glossary

Adaptation pathways	A generic term that involves the analysis of adaptation options over time to changing risk levels. It allows for flexibility in decisions where there is high uncertainty and includes adaptive management or iterative risk management over an asset's lifespan.
Adaptation Reporting Power	The Climate Change Act 2008 established the Adaptation Reporting Power (ARP). The ARP allows the Government to ask key organisations to report on the steps they are taking to prepare for climate change. There have been two cycles of adaptation reporting in the past decade and the UK is now in the third round of reporting (ARP3).
Adaptive capacity	The ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities or to respond to consequences.
Adaptive management	A process that enables uncertainty to be included in operational decision-making. For HS2, this means foreseeing potential climate change risks and ensuring assets are able to adapt during the operational phase, even if it is not viable to embed the adaptation during the initial build design (i.e. increase the resistance of the design beyond what is practicable given the uncertainty involved).
Biodiversity	The variety of life in the world or in a particular habitat or ecosystem.
Cascading impacts	Cascading impacts occur when impacts in one or more parts of an interconnected system may trigger impacts in other parts of the system.
Climate	The climate can be described simply as the 'average weather', typically looked at over a period of 30 years. It can include temperature, rainfall, snow cover or any other weather characteristic.
Climate change	This refers to a change in the state of the climate, which can be identified by changes in average climate characteristics and persist for an extended period, typically decades or longer.
Climate change adaptation	A change in natural or human systems in response to the impacts of climate change. These changes moderate harm or exploit beneficial opportunities and can be in response to actual or expected impacts.
Climate change impacts	Effects on natural and human systems of extreme weather and climate events and of climate change. Impacts generally refer to effects on infrastructure and assets due to the interaction of climate changes or hazardous climate events occurring within a specific time period and the vulnerability of the exposed system.
Climate change mitigation	Describes action to reduce the likelihood of an event occurring or reduce the impact if it does occur. This can include reducing the causes of climate change (e.g. emission of greenhouse gases) and reducing future risks associated with climate change.
Climate change projection	Projections of changes in climate variables expressed in terms of the difference between the absolute future climate and a baseline climatology for a given location, time period and emissions scenario of greenhouse gases.
Climate change resilience	The capacity of natural and human systems to retain their original form and function, and to survive and adapt in the context of the stresses and shocks imposed on them by climate change.

Glossary

Climate Change Risk Assessment (CCRA)	A Government-commissioned assessment of the risks posed to the United Kingdom by the changing climate. The current CCRA, the Government's second report (CCRA2), was produced in 2017. The next version, CCRA3, is anticipated in 2022.
Climate-related opportunities	The potential for a beneficial consequence due to a changing climate (the propensity to be beneficially affected).
Co-benefit	The positive effects that a policy or measure aimed at one objective might have on other objectives, increasing the total benefits for society or HS2.
Code of Construction Practice	Sets out the standards and procedures a developer or contractor must follow to manage potential environmental impacts when undertaking construction.
Ecological resilience	The ability of the ecosystem to robustly withstand and tolerate disturbance (for example, from the combined effects of climate change and HS2) with no significant effect on its key functions.
Extreme weather	Unusual, severe or unseasonal weather; or weather at the extremes of the range of weather seen in the past.
Freeboard allowance	The height from the maximum design level of a watercourse to: • the adjacent banks of an open channel, to provide a factor of safety against flooding; or • the soffit (underside) of any culvert or bridge above, to minimise the risk of blockage by floating debris, etc.
Greenhouse gas emissions	Atmospheric gases such as carbon dioxide, methane, chlorofluorocarbons, nitrous oxide, ozone, and water vapour that absorb and emit infrared radiation emitted by the Earth's surface, the atmosphere and clouds.
HS2 Green Corridor	A network of bigger, better-connected, climate resilient habitats and new green spaces that will run alongside the high-speed railway
HS2 Learning Legacy	The HS2 Learning Legacy shares lessons learned, good practice and innovation from the programme aimed at raising the bar in industry.
HS2 standards	Standards, procedures, guidance documents and templates set out by HS2 Ltd. HS2 developers and/or contractors must follow these standards to meet HS2 Ltd specifications.
Hybrid Bill	A hybrid Bill mixes the characteristics of a public and private Bill. The provisions in a hybrid Bill would affect the general public but would also have particular effects on specific individuals or groups.
In-combination climate change impacts	The combined effects of the impacts of the Project and potential climate change impacts on the environment.
Interdependent climate risks	The points of interaction among physical systems. Climate change also alters the nature and magnitude of risks through the interdependencies that emerge from the dynamics of large-scale, highly interconnected, complex systems.
Lock-in	Early actions or decisions that involve long lifetimes or path dependency, which will potentially increase future risk or vulnerability and that are difficult or costly to reverse later.

Glossary

Natural capital	The part of nature which directly or indirectly underpins value to people, including ecosystems, species, freshwater, soils, minerals, the air and oceans, as well as natural processes and functions.
Net zero	Condition in which greenhouse gas (or carbon dioxide) emissions are balanced by greenhouse gas (or carbon dioxide) removals over a specified period. Greenhouse gas neutrality and net zero greenhouse gas emissions are overlapping concepts.
Paris Agreement	The Paris Agreement is a legally binding international treaty on climate change, adopted at COP21 in Paris, in 2015. Its goal is to limit global warming and to encourage adaptation to the impacts of climate change.
Probabilistic climate projections	Climate projections based on an ensemble of multiple climate model runs to provide a range of potential outcomes. This better represents the uncertainty of climate science than a single 'best guess' of the impact of climate change.
Redundancy	The availability of backups or spare capacity to increase resilience.
Resilient net zero/net zero adaptation	Representing the overlapping nature of climate mitigation to achieve net zero and adaptation for the impacts of climate change to increase resilience. Resilient net zero and net zero adaptation suggest that the two concepts should be considered in harmony and are mutually dependent.
Risk assessment	An assessment of the probability of a hazard occurring that could result in an impact.
UK Climate Projections	The United Kingdom Climate Projections provide future projections of climate change for different time periods and different possible scenarios of greenhouse gas emissions. These illustrate a range of possible future changes to the UK's climate. The most recent projections were released in 2018 (UKCP18), superseding those from 2009 (UKCP09).

Abbreviations

BBV	Balfour Beatty VINCI
BREEAM	Building Research Establishment Environmental Assessment Method
CCARR	Climate Change Adaptation and Resilience Report
CCC	Climate Change Committee
CCDIA	Climate Change Design Impact Assessment
CCRA2	The UK's second Climate Change Risk Assessment
CCRA3	The UK's third Climate Change Risk Assessment
CCRIA	Climate Change Resilience and Interdependencies Assessment
CEEQUAL	Civil Engineering Environmental Quality Assessment and Award Scheme
CoCP	Code of Construction Practice
COP26	26th United Nations Climate Change Conference of the Parties
Defra	Department for the Environment, Food & Rural Affairs
DfT	Department for Transport
EIA	Environmental Impact Assessment
ESC	Environmental Sustainability Committee
HS2	High Speed Two – Britain's high-speed rail network
HS2 Ltd	High Speed Two Limited – the company building HS2
HSSE	Health, Safety, Security, and Environment
LEMP	Local Environment Management Plans
M&E	Mechanical and Electrical
MWCC	Main Works Civils Contract
UKCP09	UK Climate Projections 2009
UKCP18	UK Climate Projections 2018
WCML	West Coast Main Line

Appendix A
HS2 risk assessment

Ref.	Climate hazard	Trend and likelihood of climate hazard	Potential climate change impact	Potential climate change risk to HS2	Construction or operation	Embedded adaptation and resilience measures for Phase One and Phase 2a	Assessed risk level = likelihood of hazard X consequence of impact	Proposed additional adaptation and resilience measures	CCRA2 risk/ opportunity ref.
1	High precipitation	Likely increase in projected mean daily rainfall, especially in winter months.	Increased risk of flooding from river, surface and groundwater sources.	Flooding of track and/or overwhelming of drainage infrastructure.	Operation	Our flood risk standard requires appropriate consideration for climate change in all rail line design. This will protect the railway infrastructure from floodwater ensuring that the line will remain operational or can restart without undue delay. Drainage infrastructure is designed to cope with a one in 100-year + climate change storm event and tested against the one in 1,000-year criteria. During operation regular maintenance strategies will be undertaken to ensure continual operation of infrastructure. These are under development.	**Low**	No additional resilience measures required.	In1; In2; In4
2	High precipitation	Likely increase in projected mean daily rainfall, especially in winter months.	Increased risk of flooding from river, surface and groundwater sources.	Flooding of access roads and/or road infrastructure linked to HS2, such as access routes for HS2 staff and neighbouring landowners.	Operation	Our flood risk standard requires appropriate consideration for climate change in the design of access and maintenance routes. Additionally our highways and access drainage standard includes consideration for climate change.	**Low**	No additional resilience measures required.	In1; In2; In4
3	High precipitation	Likely increase in projected mean daily rainfall, especially in winter months.	Increased risk of flooding from river, surface and groundwater sources.	Water ingress to critical equipment, including traction power distribution sites, leading to signalling or other electronic equipment failures, requiring switch off or, possibly causing damage.	Operation	Where practical, Automatic Transformer Feeder Stations (ATFS) and Automatic Transformer Stations (ATS) will be located outside of Environment Agency flood zones. Where not practical, our standards on flood risk require ATFS/ATS to be located at flood level with sufficient freeboard above design flood level.	**Low**	No additional resilience measures required.	In1; In2; In4
4	High precipitation	Likely increase in projected mean daily rainfall, especially in winter months.	Increased risk of flooding from river, surface and groundwater sources.	Inundation of tunnels.	Operation	Many of our standards give consideration for designing resilient tunnels. This includes railway drainage, earthworks, cut and cover tunnels and tunnel portals. These standards will ensure resilience against high precipitation events.	**Low**	No additional resilience measures required.	In1; In2; In4

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Ref.	Climate hazard	Trend and likelihood of climate hazard	Potential climate change impact	Potential climate change risk to HS2	Construction or operation	Embedded adaptation and resilience measures for Phase One and Phase 2a	Assessed risk level = likelihood of hazard X consequence of impact	Proposed additional adaptation and resilience measures	CCRA2 risk/ opportunity ref.
5	High precipitation	Likely increase in projected mean daily rainfall, especially in winter months.	Increased risk of flooding from river, surface and groundwater sources.	Construction site flooding during construction phase, excavations flooded and site roads impassable. Safety risk of slips, trips and falls to construction workers.	Construction	Flood risk during construction is mitigated by the relevant CoCP and contractors are required to be aware of and take appropriate measures during extreme weather events. Measures on site will also be put in place to prevent flooding.	**Very Low**	No additional resilience measures required.	In2; In4; In5
6	High precipitation	Likely increase in projected mean daily rainfall, especially in winter months.	Increased risk of flooding from river, surface and groundwater sources.	Increased risk of scouring of bridge piers and abutments during periods of peak river flow.	Operation	The HS2 standard for flood risk alongside relevant guidance documents contains requirements for considering climate change impacts in the assessment of bridge scour.	**Low**	No additional resilience measures required.	In1; In5
7	High precipitation	Likely increase in projected mean daily rainfall, especially in winter months.	Increased soil moisture levels.	During prolonged wet winters the combination of low soil moisture deficit and rainfall will increase risk of earthworks failure and landslides.	Operation	The earthworks standard requires the effects of climate change to be assessed to determine any necessary provisions for protecting or providing resistance to any potential accelerated degradation of earthworks. The groundwater conditions adopted for design shall take account of climatic and seasonal variations (including allowances for the effects of climate change), adverse weather conditions (including extreme precipitation or prolonged drought) and surface water flows. HS2 lineside vegetation standards consider the impact of planting on long-term earthwork stability and surface erosion.	**Low**	No additional resilience measures required.	In1; In6
8	Low precipitation	Very likely increase in the number of dry days per year, especially in summer.	Increased risk of soil shrinkage around foundations of structures.	Movement of Overhead line equipment (OHE) and other shallow foundations due to soil shrinkage.	Operation	Our earthworks standard ensures that climate change effects are considered with respect to groundwater conditions adopted for design, durability of earthwork design and slope design.	**Low**	No additional resilience measures required.	In1; In8

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Ref.	Climate hazard	Trend and likelihood of climate hazard	Potential climate change impact	Potential climate change risk to HS2	Construction or operation	Embedded adaptation and resilience measures for Phase One and Phase 2a	Assessed risk level = likelihood of hazard X consequence of impact	Proposed additional adaptation and resilience measures	CCRA2 risk/ opportunity ref.
9	Low precipitation	Very likely increase in the number of dry days per year, especially in summer.	Dry weather for extended periods of time could lead to increased desiccation of soils followed by heavy rainfall.	Increased slope stability in general. However, potential earthworks failure during or immediately after summer storm events falling on desiccation-cracked soils. Volumetric instability of track earthworks and loss of track geometry.	Operation	Earthwork instability is controlled by our technical standards for lineside vegetation and our plant procurement strategy which ensure consideration of climate change. Our earthworks standard ensures that climate change effects are considered with respect to slope design and groundwater conditions adopted for design.	**Low**	No additional resilience measures required.	In1; In6; In8
10	High temperatures	Very likely increase in summer maximum temperature and number of hot days.	Increased number of extremely hot days.	Rail buckling and/or associated misalignment problems.	Operation	Asset will be designed to be resilient to climate change using existing design standards. Maintenance and monitoring measures will also be put in place.	**Very Low**	No additional resilience measures required.	In1; In13
11	High temperatures	Very likely increase in summer maximum temperature and number of hot days.	Increased number of extremely hot days.	Increased heat stress for passengers and staff on trains.	Operation	Specification of rolling stock will be considered and addressed in future design stages.	**Very Low**	No additional resilience measures required.	Pb2
12	High temperatures	Very likely increase in summer maximum temperature and number of hot days.	Increased number of extremely hot days.	Increased heat stress for staff, particularly for outdoor maintenance workers.	Operation	Risk of heat stress for staff working indoors during operation is mitigated by buildings being designed to Building Research Establishment Environmental Assessment Method (BREEAM) 'Excellent Rating' which includes appropriate climate change measures. Maintenance workers during operation will need to adhere to health and safety standards.	**Very Low**	No additional resilience measures required.	Pb1; Bu5

Appendix A

Ref.	Climate hazard	Trend and likelihood of climate hazard	Potential climate change impact	Potential climate change risk to HS2	Construction or operation	Embedded adaptation and resilience measures for Phase One and Phase 2a	Assessed risk level = likelihood of hazard X consequence of impact	Proposed additional adaptation and resilience measures	CCRA2 risk/ opportunity ref.
13	High temperatures	Very likely increase in summer maximum temperature and number of hot days.	Increased number of extremely hot days.	Increased heat stress for staff, particularly outdoor construction workers.	Construction	Risk of heat stress to staff during construction is mitigated by contractors being required to be aware of and take appropriate measures during extreme weather events and adhere to health and safety standards. These requirements are documented in our Code of Construction Practice.	**Very Low**	No additional resilience measures required.	Pb1; Bu5
14	High temperatures	Very likely increase in summer maximum temperature and number of hot days.	Increased number of extremely hot days.	Overhead line equipment (OLE) including overhead lines (OHL), traction distribution sites (ATFS, ATS) and other M&E equipment may fail to operate properly under extreme heat resulting in a reduction in electrical loading capability, failure to operate properly or damage.	Operation	Overhead Contact System assets, power assets and M&E assets will be designed to be resilient to climate change using existing design standards.	**Low**	No additional resilience measures required.	In1; In13
15	High temperatures	Very likely increase in summer maximum temperature and number of hot days.	Increased number of extremely hot days.	Increased risk of thermal expansion joints being pushed beyond their design capability, presenting a direct risk of damage to bridge structures and indirect damage of other assets dependent upon bridge.	Operation	Climate change and high temperatures are incorporated into bridge design.	**Low**	No additional resilience measures required.	In1; In13

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Ref.	Climate hazard	Trend and likelihood of climate hazard	Potential climate change impact	Potential climate change risk to HS2	Construction or operation	Embedded adaptation and resilience measures for Phase One and Phase 2a	Assessed risk level = likelihood of hazard X consequence of impact	Proposed additional adaptation and resilience measures	CCRA2 risk/ opportunity ref.
16	High temperatures	Very likely increase in summer maximum temperature and number of hot days.	Increased number of extremely hot days.	Impact of extreme hot weather could lead to increase in number of days outside the normally acceptable conditions for cooling systems on trains and affect efficiency of auxiliary power supply.	Operation	Specification of rolling stock will be considered and addressed in future design stages.	**Low**	No additional resilience measures required.	In1; In13
17	High temperatures	Very likely increase in summer maximum temperature and number of hot days.	Increased number of extremely hot days will lead to increased drying out of soils and vegetation.	Planting failures may occur due to drought.	Operation	Planting failures can have a detrimental impact on stability of embankments, this is mitigated against in our embankment design requirements which include consideration of the effects of climate change. Plant selection also takes into account climate change as described in our lineside vegetation standard.	**Very Low**	No additional resilience measures required.	Ne1; Ne4
18	High temperatures	Very likely increase in summer maximum temperature and number of hot days.	Increased number of extremely hot days will lead to increased drying out of soils and vegetation.	Extended periods of hot days may lead to a risk of grassland fires in vicinity of the route.	Operation	The risk of grassland fires in England is relatively low. Planting will be appropriately managed and maintained during the operational phase.	**Low**	No additional resilience measures required.	Ne10
19	Low temperatures	Overall decrease in prevalence of cold conditions and snowfall, but cold weather events have the potential to be more extreme.	Impacts of extreme cold weather.	Overhead line equipment (OLE) may fail due to snow overloading. Sensitive electronic equipment may fail to operate due to low temperatures or freezing.	Operation	Overhead Contact System assets, power assets and M&E assets will be designed to be resilient to climate change using existing design standards.	**Low**	No additional resilience measures required.	In1; In14

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Ref.	Climate hazard	Trend and likelihood of climate hazard	Potential climate change impact	Potential climate change risk to HS2	Construction or operation	Embedded adaptation and resilience measures for Phase One and Phase 2a	Assessed risk level = likelihood of hazard X consequence of impact	Proposed additional adaptation and resilience measures	CCRA2 risk/ opportunity ref.
20	Low temperatures	Overall decrease in prevalence of cold conditions and snowfall, but cold weather events have the potential to be more extreme.	Impacts of extreme cold weather.	Reliability of trains may reduce at low temperatures due to ice, snow or water ingress.	Operation	Specification of rolling stock will be considered and addressed in future design stages.	**Low**	No additional resilience measures required.	In1; In14
21	Low temperatures	Overall decrease in prevalence of cold conditions and snowfall, but cold weather events have the potential to be more extreme.	Impacts of extreme cold weather.	Possible negative health implications for passengers and staff, disruption to service operation.	Operation	Cold weather risk to passengers and staff during operation will be mitigated by appropriate operational management and health and safety plans.	**Very Low**	No additional resilience measures required.	Bu5; PB4
22	Low temperatures	Overall decrease in prevalence of cold conditions and snowfall, but cold weather events have the potential to be more extreme.	Impacts of extreme cold weather.	Possible negative health implications for staff, disruption to construction.	Construction	Cold weather risk to staff during construction is mitigated by contractors being aware of and taking appropriate measures during extreme weather events as described in our Code of Construction Practice.	**Very Low**	No additional resilience measures required.	Bu5; PB4
23	Low temperatures	Overall decrease in prevalence of cold conditions and snowfall, but cold weather events have the potential to be more extreme.	Impacts of extreme cold weather.	General risk of freezing of mechanical and electrical equipment.	Operation	Risk of mechanical and electrical equipment freezing is mitigated through preventative measures proposed as part of infrastructure maintenance.	**Very Low**	No additional resilience measures required.	In4; In14

Appendix A

Ref.	Climate hazard	Trend and likelihood of climate hazard	Potential climate change impact	Potential climate change risk to HS2	Construction or operation	Embedded adaptation and resilience measures for Phase One and Phase 2a	Assessed risk level = likelihood of hazard X consequence of impact	Proposed additional adaptation and resilience measures	CCRA2 risk/ opportunity ref.
24	Low temperatures	Overall decrease in prevalence of cold conditions and snowfall, but cold weather events have the potential to be more extreme.	Impacts of extreme cold weather.	Increased risk of rail breaks due to extreme cold conditions.	Operation	Asset will be designed to be resilient to climate change using existing design standards. For Phase One and Phase 2a slab track has been selected which is more resilient to extreme temperatures than ballast. Ballast will only be used in depot approaches. Maintenance and monitoring measures will also be put in place.	**Low**	No additional resilience measures required.	In4; In14
25	Low temperatures	Overall decrease in prevalence of cold conditions and snowfall, but cold weather events have the potential to be more extreme.	Impacts of extreme cold weather.	Potential increase in number of days outside normally acceptable range of conditions for heating systems on trains and affect efficiency of auxiliary power supply.	Operation	Specification of rolling stock will be considered and addressed in future design stages.	**Low**	No additional resilience measures required.	In4; In14
26	Low temperatures	Overall decrease in prevalence of cold conditions and snowfall, but cold weather events have the potential to be more extreme.	Impacts of extreme cold weather.	Freezing of earthwork surfaces can inhibit natural drainage and/ or cause frost-wedging on rock slopes, leading to instability.	Operation	Our earthworks standard ensures that climate change effects are considered with respect to durability of earthwork design and slope design.	**Low**	No additional resilience measures required.	In4; In6; In8; In14
27	Low temperatures	Overall decrease in prevalence of cold conditions and snowfall, but cold weather events have the potential to be more extreme.	Impacts of extreme cold weather.	Increased risk of ice build up on trains, over tunnel portals, which lead to infrastructure and train damage.	Operation	Asset will be designed to be resilient to climate change using existing design standards. Maintenance and monitoring measures will also be put in place. Operational restriction (speed reductions) to be implemented if sudden and extreme conditions are prevalent.	**Low**	No additional resilience measures required.	In14

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Ref.	Climate hazard	Trend and likelihood of climate hazard	Potential climate change impact	Potential climate change risk to HS2	Construction or operation	Embedded adaptation and resilience measures for Phase One and Phase 2a	Assessed risk level = likelihood of hazard X consequence of impact	Proposed additional adaptation and resilience measures	CCRA2 risk/ opportunity ref.
28	Low temperatures	Overall decrease in prevalence of cold conditions and snowfall, but cold weather events have the potential to be more extreme.	Impacts of extreme cold weather.	Increased risk of drainage systems freezing.	Operation	Asset will be designed to be resilient to climate change using existing design standards. Maintenance and monitoring measures will also be put in place.	**Low**	No additional resilience measures required.	In14
29	Wind	Likely increase in the frequency and intensity of high wind events (with some uncertainty).	Risk of windborne debris due to extreme winds.	Possible blockage of railway drainage systems due to obstructions and windborne debris from domestic or third party objects, as well as potentially landing on track and causing damage to OHL.	Operation	The Plant Procurement Strategy specifies that specific tree species will be avoided to minimise the risk associated with leaf fall. Our technical standard on lineside vegetation management includes improving the resilience of rail infrastructure to the impacts of climate change.	**Very Low**	No additional resilience measures required.	In1; In11
30	Wind	Likely increase in the frequency and intensity of high wind events (with some uncertainty).	Increased stress on trees due to extreme winds leads to risk of trees/branches falling and changes to leaf fall patterns. Exacerbated by other factors e.g. seasonal precipitation and temperature patterns.	Increased disruption from autumn leaf fall or changed temporal patterns of leaf fall.	Operation	The Plant Procurement Strategy specifies that specific tree species will be avoided to minimise the risk associated with leaf fall. Our technical standard on lineside vegetation management includes improving the resilience of rail infrastructure to the impacts of climate change.	**Very Low**	No additional resilience measures required.	In1; In11

Appendix A

Ref.	Climate hazard	Trend and likelihood of climate hazard	Potential climate change impact	Potential climate change risk to HS2	Construction or operation	Embedded adaptation and resilience measures for Phase One and Phase 2a	Assessed risk level = likelihood of hazard X consequence of impact	Proposed additional adaptation and resilience measures	CCRA2 risk/ opportunity ref.
31	Wind	Likely increase in the frequency and intensity of high wind events (with some uncertainty).	Increased stress on trees due to extreme winds leads to risk of trees/branches falling and changes to leaf fall patterns. Exacerbated by other factors e.g. seasonal precipitation and temperature patterns.	Wind interference with construction equipment, particularly temporary equipment, and workers.	Construction	Climate change may increase wind speeds however there is high uncertainty in projections and changes are not considered to be significant by the '2020s'. Therefore additional resilience measures are not required during the construction phase.	**Very Low**	No additional resilience measures required.	In11
32	Wind	Likely increase in the frequency and intensity of high wind events (with some uncertainty).	Increased stress on infrastructure due to extreme winds.	Failure of or damage to parts of structure or infrastructure as a result of changes in extreme winds and gustiness. Noise barriers and fencing are likely to be most at risk.	Operation	Whilst HS2 structures are generally deemed not to be sensitive to wind loading, as there are no slender/suspension bridge types, auxiliary components such as parapets may be vulnerable to wind events. With long design lives building roofs may be vulnerable to wind events. These risks will be considered and mitigated through measures to be developed during future design stages. Consideration for wind exposure to sign design is included within HS2 standards.	**Very Low**	No additional resilience measures required.	In1; In11

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Ref.	Climate hazard	Trend and likelihood of climate hazard	Potential climate change impact	Potential climate change risk to HS2	Construction or operation	Embedded adaptation and resilience measures for Phase One and Phase 2a	Assessed risk level = likelihood of hazard X consequence of impact	Proposed additional adaptation and resilience measures	CCRA2 risk/ opportunity ref.
33	Wind	Likely increase in the frequency and intensity of high wind events (with some uncertainty).	Increased stress on infrastructure due to extreme winds.	Failure of or damage to electrical and mechanical equipment including aerial bus bars/connections of outdoor switchgear at traction power distribution sites may fail or be damaged.	Operation	Climate change may increase wind speeds however there is high uncertainty in projections. This risk will be considered during future design stages with potential mitigation through design change or operational management.	**Very Low**	No additional resilience measures required.	In1; In11
34	Lightning	Increases in the number of lightning days are projected for all four seasons, with the largest projected increases occurring in summer, associated with storms.	Increased risk of lightning strikes.	Indirect damage to buildings, structures, line side equipment and equipment and cabling traction power distribution sites from lightning strikes damaging trees.	Operation	Risk of damage to assets is partially mitigated by planted trees being positioned to ensure that if struck by lightning they would not fall into the route of train.	**Low**	No additional resilience measures required.	In1; In11
35	Lightning	Increases in the number of lightning days are projected for all four seasons, with the largest projected increases occurring in summer, associated with storms.	Increased risk of lightning strikes.	Direct damage to buildings, structures, lineside equipment and equipment and cabling traction power distribution sites from lightning strikes.	Operation	Direct risk of lightning strikes will be addressed during further design stages.	**Low**	No additional resilience measures required.	In1; In11

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Ref.	Climate hazard	Trend and likelihood of climate hazard	Potential climate change impact	Potential climate change risk to HS2	Construction or operation	Embedded adaptation and resilience measures for Phase One and Phase 2a	Assessed risk level = likelihood of hazard X consequence of impact	Proposed additional adaptation and resilience measures	CCRA2 risk/ opportunity ref.
36	Lightning	Increases in the number of lightning days are projected for all four seasons, with the largest projected increases occurring in summer, associated with storms.	Increased risk of lightning strikes.	Safety risk to construction equipment and workers.	Construction	Safety risk to construction workers due to lightning is mitigated by contractors taking appropriate measures to manage extreme weather events as required by our Code of Construction Practice.	**Low**	No additional resilience measures required.	In11

Appendix B
Mapping our report to UK Government risks

B.1 CCRA2 rail infrastructure risks

ARP3 reports are intended to report on the risks identified in the UK Government's second Climate Change Risk Assessment (CCRA2), published in 2017, and can also cover additional risks and opportunities identified by organisations. Table B-1 below presents the risks and opportunities identified by Defra in the ARP3 guidance for rail infrastructure and how they have been incorporated into our adaptation report.

Table B-1 – CCRA2 risks and opportunities identified by Defra for rail infrastructure[1]

CCRA2 rail infrastructure (In) risk or opportunity reference	CCRA2 risk/opportunity	Defra's CCRA2 score	Defra's rationale for CCRA2 scoring	Section reference in this Adaptation Report	HS2's risk assessment score
In1	Risks of cascading infrastructure failures across interdependent networks.	More action needed	More action needed to enhance arrangements for information sharing in order to improve understanding of critical risks arising from interdependencies.	**Section 5.2** **Section 6** **Section 8**	**To be quantified through ongoing work**
In2	Risks to infrastructure services from river, surface water and groundwater flooding.	More action needed	More action needed to manage increasing risk to existing assets and networks and ensure increased risk is accounted for in design and location of new infrastructure.	**Section 3** **Section 4.3** **Section 5**	**Low / very low**
In3	Risks to infrastructure services from coastal flooding and erosion.	More action needed	More action needed to manage increasing risk to existing networks (including flood and coastal erosion risk management infrastructure) from sea level rise and increased rate of erosion.	Not directly relevant to HS2 assets (as HS2 is not located near to the coast). Potentially relevant to HS2 supply chain and interdependencies covered in **Section 6**.	**Not applicable**
In4	Risks of sewer flooding due to heavy rainfall.	More action needed	More action needed to deliver sustainable drainage systems, upgrade sewers where appropriate and tackle drivers of increasing surface runoff (e.g. impermeable surfacing in urban areas).	**Section 5.2** **Section 6**	**Low**

1 **consult.defra.gov.uk/environmental-quality/adaptation-reporting/supporting_documents/strategyarp12022018.pdf**

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CCRA2 rail infrastructure (In) risk or opportunity reference	CCRA2 risk/opportunity	Defra's CCRA2 score	Defra's rationale for CCRA2 scoring	Section reference in this Adaptation Report	HS2's risk assessment score
In5	Risks to bridges and pipelines from high river flows and bank erosion.	Research priority	More research needed on implications of projected changes in river flows on future risk of scour/erosion.	**Section 4.3**	**Low**
In6	Risks to transport networks from slope and embankment failure.	More action needed	More action needed to locate and remediate embankments and cuttings at risk of failure.	**Section 4.3** **Section 5.2**	**Low**
In8	Risks to subterranean and surface infrastructure from subsidence.	Watching brief	Monitor changes in temperature and rainfall patterns to update assessments of subsidence risk.	**Section 4.3** **Section 5.2**	**Low**
In11	Risks to energy, transport and digital infrastructure from high winds and lightning.	Research priority	More research needed on the implications of increased vegetation growth rates on future risks of damage from falling trees during storms.	**Section 4.3**	**Low / very low**
In13	Risks to transport, digital and energy infrastructure from extreme heat.	Sustain current action	Continue current actions to reduce risks, maintenance and renewals of infrastructure networks.	**Section 4.3** **Section 5.2**	**Low / very low**

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CCRA2 rail infrastructure (In) risk or opportunity reference	CCRA2 risk/opportunity	Defra's CCRA2 score	Defra's rationale for CCRA2 scoring	Section reference in this Adaptation Report	HS2's risk assessment score
In14	Potential benefits to water, transport, digital and energy infrastructure from reduced extreme cold events.	Sustain current action	Continue current actions to reduce risks, including cold-weather planning and response.	Not covered in our climate change risk assessment and therefore not currently highlighted in this adaptation report but impacts on HS2 assets due to extreme cold events highlighted in **Section 4**. The CCC's CCRA3 evidence report has removed this potential benefit, as there is some evidence to suggest extreme cold events will not decrease with climate change due to impacts on arctic air currents/ocean currents.	**Not covered in risk assessment**
Pb2	Risks to passengers from high temperatures on public transport.	Sustain current action	The action underway in London to assess and manage risks of overheating on public transport should continue, together with similar action as needed elsewhere in the UK.	**Section 4.3** **Section 5.2**	**Very low**

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CCRA2 rail infrastructure (In) risk or opportunity reference	CCRA2 risk/opportunity	Defra's CCRA2 score	Defra's rationale for CCRA2 scoring	Section reference in this Adaptation Report	HS2's risk assessment score
Bu5	Risks to business from reduced employee productivity due to infrastructure disruption and higher temperatures in working environments.	Research priority	More research needed on disruption to ICT, power and transport infrastructure which prevents workers accessing premises or working remotely, and on impacts of higher temperatures on employee safety and productivity.	This risk has not been covered in our climate change risk assessment. This risk is focused on the risk to businesses rather than infrastructure. This risk relates to operational rail infrastructure being disrupted, which is not relevant to HS2 at present because it is not yet operational. HS2 has embedded adaptation and resilience measures to avoid and recover from climate-related disruption and these are included under other climate risks. In the construction phase, our Code of Construction Practice requires contractors to consider and manage extreme weather events.	**Not covered in risk assessment**

Appendix B
Mapping our report to UK Government Risks

B.2 CCRA3 rail infrastructure risks

The Climate Change Committee (CCC) published its third independent report on the UK's risks from climate change (CCRA3) in June 2021.[2] For the purposes of this report, we have identified comparable climate change risks and opportunities for the rail infrastructure sector within the CCRA2 from Defra and the CCC's independent advice to Government for the CCRA3 report (Table B-2). Risks and opportunities have been aligned where possible. However, the CCC has removed and combined some risks and opportunities which were included in CCRA2.

Table B-2 demonstrates that HS2's Adaptation Report (ARP3) includes good coverage of suggested risks for the CCRA3, as well as the relevant risks from CCRA2. Specifics of where CCRA2 and the suggested risks from the CCC have been addressed in the adaptation report can be found in Table B-1.

Table B-2 – Alignment of CCRA2 and CCC's CCRA3 evidence report risks and opportunities, and urgency scoring for rail infrastructure

CCRA2 rail infrastructure (In) risk/opportunity	CCRA2 urgency score	CCC's CCRA3 report – rail infrastructure (I) risk/opportunity	CCC's urgency score
In1: Risks of cascading failures from interdependent infrastructure networks	More action needed (UK)	I1: Risks to infrastructure networks (water, energy, transport, ICT) from cascading failures	More action needed (UK)
In2: Risks to infrastructure services from river, surface water and groundwater flooding	More action needed (UK)	I2: Risks to infrastructure services from river, surface water, and groundwater flooding	More action needed (UK)
In3: Risks to infrastructure services from coastal flooding and erosion	More action needed (England)	I3: Risks to infrastructure services from coastal flooding and erosion	Further investigation (UK)
In4: Risks of sewer flooding due to heavy rainfall	More action needed (UK)	The CCC has removed this risk by combining it with I2 (surface water flooding)	–
In5: Risks to bridges and pipelines from high river flows and bank erosion	Research priority (UK)	I4: Risks to bridges and pipelines from flooding and erosion	Further investigation (UK)
In6: Risks to transport networks from slope and embankment failure	More action needed (UK)	I5: Risks to transport networks from slope and embankment failure	More action needed (UK)
In8: Risks to subterranean and surface infrastructure from subsidence	Watching brief (UK)	I7: Risks to subterranean and surface infrastructure from subsidence	Further investigation (UK)
In11: Risks to energy, transport and digital infrastructure from high winds and lightning	Research priority (UK)	I12: Risks to transport from high and low temperatures, high winds and lightning CCC has separated transport out from other infrastructure and included more climate hazards in this risk	More action needed (UK)
In13: Risks to transport, digital and energy infrastructure from extreme heat	Sustain current action (UK)	The CCC has removed this risk by combining this with I12	–
In14: Potential benefits to water, transport, digital and energy infrastructure from reduced extreme cold events	Sustain current action (UK)	The CCC has removed this opportunity	–

2 **theccc.org.uk/publication/independent-assessment-of-uk-climate-risk/**

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CCRA2 rail infrastructure (In) risk/opportunity	CCRA2 urgency score	CCC's CCRA3 report – rail infrastructure (I) risk/opportunity	CCC's urgency score
Pb2: Risks to passengers from high temperatures on public transport	Research priority (UK)	H1: Risks to health and wellbeing from high temperatures The CCC has removed this risk by combining this with H1	More action needed (UK)
Bu5: Risks to business from reduced employee productivity, due to infrastructure disruption and higher temperatures in working environments	Research priority (UK)	B5: Risks to business from reduced employee productivity due to infrastructure disruption and higher temperatures in working environments	Further investigation (UK)

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